A Cost benefit analysis of bioethanol production from cereals in Sweden- A case study approach

Johanna Larsson

SLU, Department of Economics *Thesis 472*
Degree Thesis in Business Administration *Uppsala 2007*
D-level, 30 ECTS credits
ISSN
ISRN SLU-EKON-EX-472 SE

- A Cost benefit analysis of bioethanol production from cereals in Sweden- A case study approach

- En Cost benefit analys av etanolproduktion med cerealier som råvara i Sverige- En fallstudie

Johanna Larsson

Handledare:
SLU: Professor Hans Andersson
Cranfield University: Professor Joe Morries

© Johanna Larsson

Sveriges lantbruksuniversitet
Institutionen för ekonomi
Box 7013
750 07 UPPSALA

ISSN 1401-4084
ISRN SLU-EKON-EX-No.472 –SE

Tryck: SLU, Institutionen för ekonomi, Uppsala, 2007

ABSTRACT

This study makes an attempt to evaluate the Net Present Value of production of bioethanol. The study is predominately focusing on the production of bioethanol with cereals as feed stock. The study is a case study of the Swedish farmers cooperative (SvL) and is carried through with aim to get an aggregated social value for bioethanol production for the case study company with Sweden as a reference group. The method used in the study is a Cost Benefit Analysis (CBA) approach where an excel model has been developed and used to derive results. The CBA approach considers the difference between with and without the project approach and the opportunity cost is essential. It is assumed that without this investment the land would be used for cultivation of cereals for human food consumption. It is found that bioethanol production from cereals at SvL's production plant can lead to environmental net benefits in form of reduced overall CO_2 emissions. It is also found that there is net energy saving as well a reduction of the overall oil dependency by this production process.

The social net benefit is however dependent on how expensive it is assumed to be to emit CO_2 to the atmosphere. This figure also varies with the level of discount rate that is used for the calculation. It is here argued that it is reasonable to put a high cost on CO_2 emissions due to the insecurities regarding climate change. It is also argued that the importance of investments in environmentally friendly technologies decreases when a high discount rate is used. The net benefits are distributed both within and outside the Swedish society. The environment, the maintenance suppliers and the bank are large net gainers. There is however a considerable negative distribution for the government due to the total tax exemption on bioethanol. The results can however change with changes in the assumptions. If it is assumed that the land used for cultivation of wheat for bioethanol not would be cultivated at all without the project, the results changes. In that case also the CO_2 emissions and energy input during the cultivation and transportation of the wheat should burden the social NPV. This results in a lower social net benefits and a lower total reduction of CO_2 emissions and oil dependency.

SAMMANFATTNING

I detta examensarbete görs ett försök att estimera samhällsvärdet av inhemsk etanolproduktion, studien fokuserar huvudsakligen på etanol från säd som råvara. Beräkningarna är baserat på en fallstudie av Svenska Lantmännens och har som syfte att estimera det samhällsekonomiska värde som denna och liknande produktion har för det svenska samhället. En ”Cost benefit analys (CBA)” används i denna studie där en modell i Excel upprättas och används för beräkningar. En CBA jämför skillnader mellan scenariot ”med” eller ”utan” projektet vilket gör att alternativkostnaden är mycket viktig.

Här förutsätts det att om etanolproduktion inte skulle förekomma skulle marken istället uppodlas av säd för matkonsumption. Studien finner att etanolproduktion med säd som råvara kan ge miljöfördelar i form av nettominskning av koldioxidutsläpp. Det visas också att sådan produktion kan leda till minskat energi och oljeberoende. Den samhällsekonomiska nettoeffektens storlek beror dock på hur högt man värderar utsläpp av koldioxid. Detta värde varierar bland annat med den valda diskonteringsräntan. Det argumenteras i denna studie att utsläppen ska värderas relativt högt på grund av den osäkerhet som finns kring framtida effekter och kostnader för koldioxidutsläpp. Det poängteras också att investeringar i miljövänlig teknik minskar med ökad diskonteringsränta. Studien finner att värdet av investeringen i etanolproduktion är distribuerade både i och utanför Sverige där miljön, byggföretag, banksektorn är de stora vinnarna i Sverige. Regeringen är dock, på grund skattelättnaden på etanol, den stora förloraren.

Det måste poängteras att resultaten förändras om antagandena i studien förändras. Om det i stället skulle antas att marken som används för produktion av säd till etanolproduktion inte skulle uppodlas alls om inte etanolproduktion skulle förekomma förändras till exempel resultatet. Under sådana antaganden måste också den energi och de koldioxidutsläpp som uppkommer under odling och transport inkluderas i beräkningarna och belasta kalkylen. Detta skulle resultera i en lägre nettoreduktion vad gäller koldioxidutsläpp och en generell minskning av svenskt oljeberoende.

ACKNOWLEDGEMENTS

The author wishes to show her appreciation to the staff at SvL for their information and helpfulness during meetings and the site visit. Many thanks also to Sven Bernesson and Mats Edström for your kind and helpful attitude.

The author also wants to thank the two supervisors, Professor Joe Morris at Cranfield University and Professor Hans Andersson at the Swedish University of Agriculture and Science.

Many thanks also to my family, my friends and to my boyfriend.

LIST OF TABLES AND FIGURES

Figures

Tables

LIST OF ABBREVIATIONS

CBA	Cost-Benefit Analysis
EW	Equity weighting
SDR	Social discount rate
SvL	Svenska Lantmännen, the Swedish farm cooperation
NPV	Net present value
IRR	Internal rate of return
SCC	Social cost of carbon
SEK	Swedish Kronor

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

This chapter gives an introduction to the research area and an explanation of why the research has been carried through. Here the aim, objectives and specific research questions are introduced.

1.1 Background to Research

The global temperature record indicates that the earth has warmed up by about half a degree Celsius since the beginning of the last century and that this development has speed up during the last decades with 10 of the average warmest years since 1850 occurring from 1990 until 2006. (SEA, 2005, DEFRA, 2006, Swedish EPA, 2006, King, 2005) The emissions of carbon dioxide have nearly doubled over the three last decades, from being less than 15 000 M ton in 1971 to be nearly 25 000 M ton per year in 2003. This trend mirrors the economic development and the need for more energy. During this period the global demand for energy has increased largely and IEA, (2005) is anticipating that this trend will continue and that the CO_2 emissions will have increased by another 60% by year 2030. (IEA, 2005) The Kyoto protocol, signed by 163 countries worldwide, is a step towards a reduction of the overall greenhouse gas emissions. This protocol states that by the end of the period 2008-2012 the level of greenhouse gas emissions should be 5% 1990's levels. (UNCCCP, 2006) The EU 15 adopted a collective target to reduce EU emissions by 8% during this time and this is divided between the member countries after their initial level of emission and economic circumstances. (DEFRA, 2006) The Kyoto protocol, together with concerns about for example increasing oil dependency has been driver's for implementations of a range of directives. (EC, 2006b)

The transport sector stands for a large part of the emissions of greenhouse gases in the world since this sector currently accounts for more than half of the world's total oil consumption. (IEA, 2005) In the EU the transport sector is nearly as oil dependent and it accounts for more than 30% of the total energy consumption. The structure of the transport sector with small oil dependent units (cars, buses) makes this sector quite difficult and expensive to change. This sector has therefore been considered to be the main reason for the EU failing to meet the Kyoto targets. (EC, 2004b) The EU has however set ambitious targets for creating a market for biofuels in order to decrease the overall emission of CO_2 from this sector but also to improve energy security and to sustain European competitiveness. (EC, 2006a) The Biofuels directive, (2003/30/EC) suggests that member countries in the union should introduce biofuels into the transport sector. (Swedish Government, 2004) This is also a trend in many other countries around the world. (EIA, 2005)

Biofuels is any fuel that derives from biomass, which means that it during combustion only is emitting green CO_2 .Bioethanol and biodiesel are the biofuels that are used the most today since these can be used with none or little modification in existing vehicles. (EC, 2004a,) The cost for production of biofuels is currently relatively higher per unit of energy than fossil fuels and it therefore has to be subsidised within Europe if domestic production is wanted. In Europe many countries have introduced a tax exemption on biofuels in order to stimulate production and consumption. Some countries, Spain, Germany, Italy, and Sweden, have chosen to use a total tax exemption whereas other countries are using a smaller reduction. In the last years the domestic production within these countries has increased noticeable. (Swedish Government, 2004)

There are a range of raw materials and methods available for production of biofuels. For biofuels the reduction of greenhouse gases emissions and energy efficiency however varies with the production system, the raw materials used and the way that the waste products are treated. (IEA, 2005, EC, 2006a) Within the EU the production of biodiesel, made from rapeseed, is the largest biofuels but bioethanol production from cereals is also developing very fast within the EU. (EC, 2004a)

1.2 The research problem

The tax exemption, encouraged by the biofuels directive, motivates domestic producers within the EU to invest in biofuels plants and it also encourages petrol suppliers to use biofuels as a blend into the petrol and diesel. This is a way to carry through the biofuels directive and it is a way to reduce the oil dependency and the greenhouse gas emissions from the transport sector. (Swedish EPA, 2005, EC, 2006a) It can be looked at as a way to stimulate domestic economic activity and give rise to employment, tax incomes and other benefits. For the EU the biofuels directive also goes in line with the CAP (common agricultural policy) which is stimulating the creation of open landscapes and rural development. (SAA, 2004) The question is however whether it is favourable from the society's point of view to support domestic production of biofuels since the cost for the society in form of lost tax revenues potentially can be relatively high. To answer this question it is necessary to estimate and value the benefits and costs that are generated. The level and value of the reduced greenhouse gases, changes in oil dependency and whether domestic production also brings other benefits or costs for the society has to be investigated, measured and valued in order to understand this. A way of doing this is to look at a case study and map out society's benefits and costs in order to get an aggregated value. There is a need to identify net benefits captured by market prices and also externalities that are not captured by market prices. (Brown & Campbell, 2003)

Sweden is the country in Europe with the highest target for biofuels consumption, 3% for 2005. This development has been supported with total tax exemption for bioethanol. Today Sweden is the only country in Europe that is consuming more bioethanol than it is producing. (EC, 2006) Sweden is a large country with huge biomass potential in terms of forest and cropland and it should therefore potentially be able to increase its production of biofuels for the transport sector in the future. (SAA, 2004) The question is whether production of bioethanol in Sweden can be cost effective and whether the production brings benefits to the country other than the revenues gained by the producer? In order to understand and to be able to measure costs and benefits with bio ethanol production this thesis uses Svenska Lantmännen, (SvL) for the calculations. SvL is the only relatively large producer of bioethanol in Sweden and it is using grain for its production. This thesis therefore focuses on bioethanol and then in particular production from grain. The study identifies and put a value on the costs and benefits which arise through SvL's production of bioethanol from the society's perspective. The aggregated value can then be used to understand the achieved benefits and compare it to desirable goals

1.3 Research Aim, Objectives and Research questions

1.3.1 Research Aim

The aim of this thesis is to estimate the social net benefits associated with domestic production of bioethanol from cereals in Sweden and to understand the distributional effects of them.

`

1.3.2 Objectives

- To estimate a social value of the bioethanol production from grain through identifying the ”real” costs for inputs and outputs that are used in domestic production of bioethanol and to estimate the environmental benefits in monetary terms of the CO_2 reduction of the produced good.
- To recognize the distributional effects of the social net benefits.

1.3.3 Research questions

- What are the inputs and outputs in the production of bioethanol from grain and what is the opportunity cost of the inputs?
- What is the value of the inputs when taxes and subsidies are taken away?
- What is the total aggregated social value associated with SvL's production of bioethanol?
- How much does it cost the society to emit CO_2?
- How is the net benefit distributed among groups within the Swedish society?
- Who are the gainers and who are the losers?

CHAPTER 2

SOCIAL APPRAISAL OF BIOETHANOL PRODUCTION

This chapter presents the findings from literature and it is starting with the background information on biofuels. It then gives information that is important and relevant to carry through the research so that the aim and objectives can be fulfilled satisfactory. There is a focus on the concept and the theory of the Cost benefit analysis and how this is carried through in practise. The most relevant concepts and problems are explained and discussed in order understand how to apply the method in a case study in chapter four. A conceptual framework is presented in the end of the chapter explaining the concept which the further research is based upon.

2.1 What is bioethanol

Bioethanol, C_2H_5OH, is a colourless fluid that can be produced via a fermentation process or synthetically. In the former raw material from the forest or agriculture that contains sugar, starch or cellulose is used and in the latter the ethanol is produced from fossil fuels. Synthetic ethanol constitutes about 5% of the total production and bioethanol about 95%. In this report synthetically produced ethanol is not further concerned. (SAA, 2004) Bioethanol can be produced from a number of different raw materials from the forest and the agriculture. Sugar canes and grain crops are the most commonly used feedstock for bioethanol in the world today. In countries with large forest, like Canada and Sweden, there are research projects going on regarding cellulose crops such as forestry waste and the fluid resulting from the paper and pulp industry. (SAA, 2004, IEA, 2004) It is also possible to produce bioethanol from other types of biomass waste. Spanish researchers are for example looking at straw as a possible material for bioethanol production. (EC, 2004)

In the production process of bioethanol there is a fermentation process that is fermenting the sugar in the raw material into bioethanol. The sugar content is important for the effect; therefore feedstock with high sugar content is preferable. Starch and cellulose first have to be converted into sugar in a process where enzymes are added. The figure below illustrates the production steps by feedstock and conversion techniques. It illustrates the most common harvest techniques used for bioethanol production, the process of conversion to sugar, the most commonly used source for process heat and the co-products given for potential feed stocks. (IEA, 2004) In the fermentation process the sugar is transformed to ethanol and CO_2. In this stage the bioethanol has an alcohol content of between 10-16%. The fluid then has to be distilled, a process that takes the water away and leaves a fluid with about 95% alcohol content. This can then be further treated and can then be a liquid with an alcohol content that is very close to 100%. (SAA, 2004) Bioethanol is most commonly used as a blender in petrol. It can however advantageous be used to a much higher percentage in modified flexible fuel vehicles (IEA, 2004)

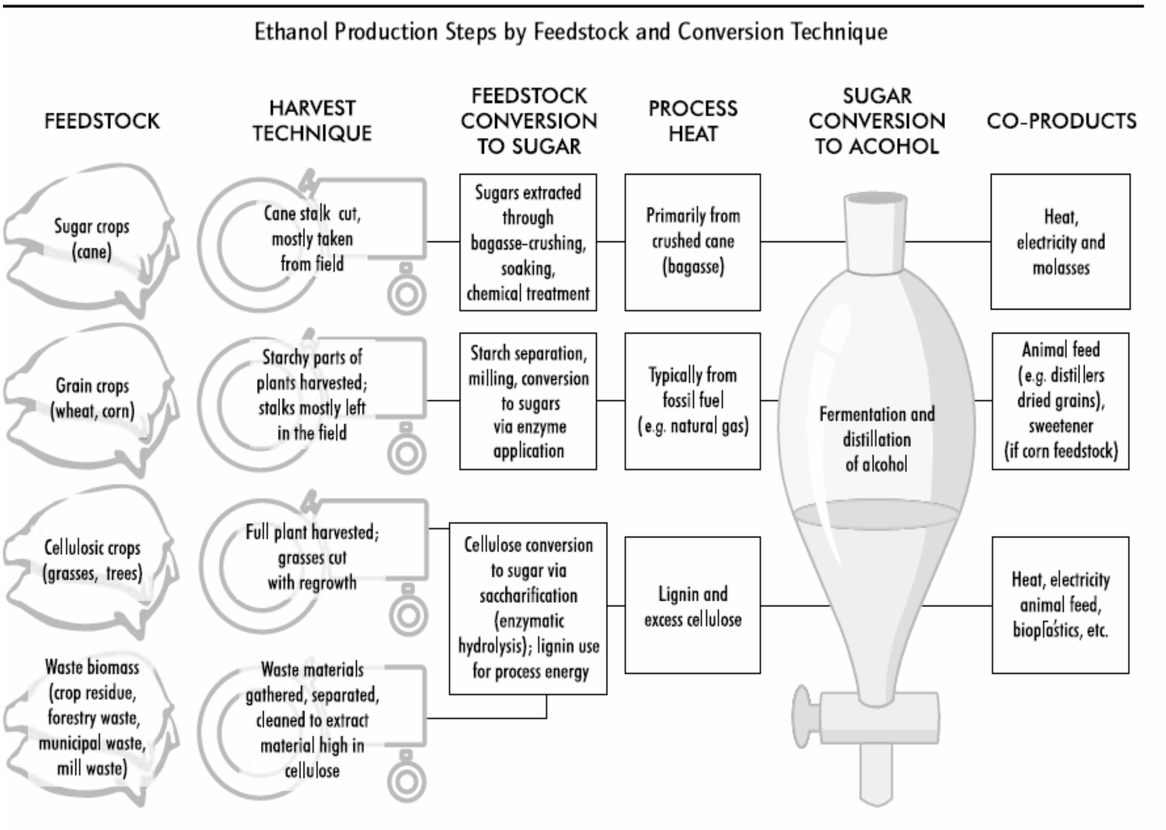


Figure 2.1 Illustration of ethanol production (Source IEA, 2004)

2.1.2 Overview over the bioethanol market and potential benefits from increased production

Even thought bioethanol is the largest biofuels in the world it is still very small share of the total energy used in the transport sector. The largest producers in the world 2004 were Brazil with 9.9 million tonnes and the US with a production of 8.4 million tonnes. The bioethanol produced in Brazil is essentially produced from sugar cane whereas the bioethanol from the USA is mostly produced from corn. (EC, 2004a) In Brazil there has been a legal requirement of mixing the petrol for transport with between 18-26% bioethanol since the oil crisis in the 70tis. Other countries in South America have taken after Brazil and have started to produce bioethanol from sugar canes and put a legal requirement on blending into petrol in order to reduce their oil dependency, to get exporting incomes and to introduce alternative crop to the cocaine plants. (SAA, 2004)

In the US the bioethanol production is currently increasing very fast. One big reason for this is that bioethanol increases the octane number of petrol which is favourable and it gives a positive effect on air pollution. (IEA, 2004) In Asia there are a number of countries that also have problems with pollution in the big cities and are heavily oil dependent. From January 1st 2003 for example nine Indian states were required to mix the petrol with 5% bioethanol in order to deal with these problems. India was 2004 the world's second largest sugar cane producer. (IEA, 2004) China is considering similar methods. In Australia the blending is up to 10% in petrol, the bioethanol mainly being produced from grain. (SAA, 2004)

In the EU the biofuels directive 2003/30/EC states that member states should ensure that biofuels and other renewable fuels are placed on their markets. The reference value is that 2% of the total energy content of all diesel and petrol used for transport purposes 2005 and 5.75% in 2010 should come from biofuels and other renewable sources. This is one way for the commission to reduce greenhouse and make the EU less dependent on oil. (EC, 2003) The European figures for ethanol production are more modest than the figures in the US and Brazil even though there is a positive trend. Figures for 2004 tell that about 0.5 million tonne ethanol was produced within the European Union. Spain is the largest producer in Europe presently, 194 000 tonnes during 2004. France was the second largest producer with 102 000 tonnes, followed by Sweden 52 000 tonnes and Poland with about 36 000 tonnes. (Europe also produced about 2 million tonne biodiesel 2004.) Europe is however supporting domestic production of biofuels by a protective customs, which is currently 1.80 SEK per litre imported bioethanol (Swedish Government, 2007) In Europe the feedstock used for bioethanol is predominately wheat, sugar beet and waste from the wine industry. (EC, 2005) It is estimated that between 4-13% of total agricultural land in the EU would be needed to produce the biofuels needed to fulfil the directive from domestically produced biofuels. The vision is however that up to one-forth of the transport fuel used in the EU could be met by biofuels within 25 years if various techniques and a wide range of biomass resources are used. (EC, 2006a, EC, 2004b)

Generally biofuels provide reductions in greenhouse gas emissions compared to petrol and diesel in wheel-to-wheel calculations. This is one of the most important drivers in the transport sector to promote biofuels. (EC, 2006a) According to IEA (2004) there can be large net reductions in CO_2 equivalent emissions compared to diesel and petrol. IEA argues therefore that biofuels can play an important role in decreasing the greenhouse gases. The CO_2 emitted by vehicles does not contribute to new emission since virtually all the CO2 emitted is already part of the carbon cycle since it was absorbed by plants during growth and released during combustion. The amount of greenhouse gases emitted and the level of oil savings is however dependent of the method used and the feedstock for production of the biofuels. (IEA, 2004)

Figure 2.2 below shows the estimated reductions of CO_2 equivalents for bioethanol and biodiesel for different feedstock. The black line indicates the range of estimates in different studies and the grey staples are an average of these studies. (The figures for bioethanol is compared to petrol and biodiesel is compared to diesel) It is shown that bioethanol produced from grain and sugar beet reduces CO_2 the least whereas sugar cane and cellulose feedstock reduces CO_2 the most. The type of process heat and the sugar content plays a decisive role for these results since the production process of bioethanol is rather energy intensive. Bioethanol produced from grain and sugar beet in US and the EU often uses fossil fuels in the production process. In Brazil however, in the new plants the crushed sugarcanes are used for process heat. This together with the raw material's naturally high sugar content makes these type of production much more CO_2 efficient. (IEA, 2004)

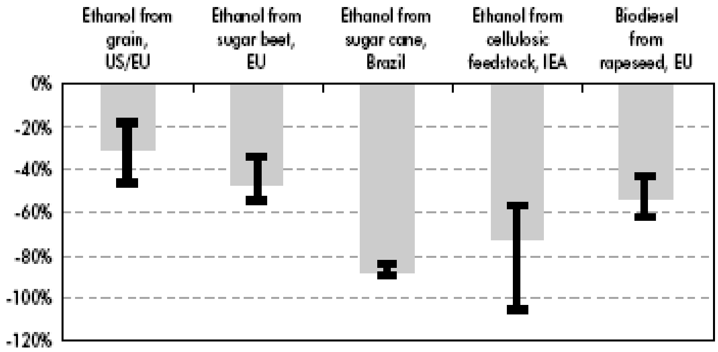


Figure 2.2 Estimated CO_2 equivalent reductions from bioethanol compared to conventional fuels. (Source: IEA, 2004)

2.2 How to assess the value of bioethanol production

In order to assess the monetary value of production and consumption of bioethanol made from cereals in Sweden it has to be reviewed properly. One way of estimating the aggregated value of domestic production of bioethanol is to make a cost benefit analysis over the proposed project. The information given through this analysis can be used to compare with alternative decision possibilities. Here theory of the cost-benefit analysis method is stated in order to report on different aspects of the method which is applied in chapter four.

2.2.1 What is Cost Benefit Analysis (CBA)

A Cost Benefit Analysis (CBA) is a method used by decision makers in order for them to predict and evaluate the value of an undertaken project. It is a process of identifying, measuring and comparing the social benefit and costs of an investment project or a programme. All benefits and costs of a project are included in the calculations, consisting of private and social, direct and indirect, tangible and intangible. (Brent, 1997) CBA is an attempt to appraise investments projects in a way that corrects for market failures. Externalities are a type of market failures that arise where there are no market connection between a person consuming or producing a good and the persons that are affected by that good. (Perman, 2003) In order words, if it is a negative externality the cost doesn't impose on the person causing the damage because there are no market prices so the cost has to be carried by others. In contrast if the externality is positive it is the other way around, the cost is not imposed on the person enjoying the benefit. (Brown & Campbell, 2003)

Projects evaluated by a CBA can either be private or public. Projects that are private can lead to benefits and cost that are not limited to the firm but also affects other people in the society. A project implemented by a private firm can for example generate benefits in form of taxes, provide employment in the area, but can also generate costs that are not paid by the private firm such as costs for environmental degradation. CBA can analyse all sorts of public projects such as pollution control and tax and regulatory regimes but is often thought as a good tool to evaluate physical projects. (Brown & Campbell, 2003)

The CBA calculations are used to measure the difference a project makes, the differences between scenario *with the project* and a scenario *without the project*. CBAs are used to evaluate and understand efficiency and value to different stakeholders given through the project. If the project wouldn't have been carried through the resources could have had an alternative use, the value of this is identified as the project's opportunity cost. (Brown & Campbell, 2003) The project that is not carried through is a forgone benefit or opportunity cost of choosing the preferred action. (Daffern & Grahame, 1990) In a competitive market, without distorting taxes and subsidies, the market price is exactly its opportunity cost of production; the willingness to pay for costumers equals the value of the resources used to produce the good. (Brent, 1997) Figure 2.3 illustrates the competitive market; in point E the last unit supplied equals the opportunity cost of production, to the left the value of an extra unit is higher than the opportunity cost whereas the value to the right exceeds the opportunity cost. If there where no externalities or other distorting effects on the market there would be no need to make a CBA since all resources where allocated in the for the private individual and society best way. If the market on the other hand is non-competitive or distorted the demand and supply prices are not the same in equilibrium and they therefore have to be valued according to certain rules to correctly mirror their true value. (Brown & Campbell, 2003) The prices for inputs needs to be adjusted to constitute the real cost of production by taking distorting effects away such as taxes, subsidies and import duties. This is referred as shadow pricing and it has this name because it has no existence apart from its usage in social valuation. (Perman, 2003)

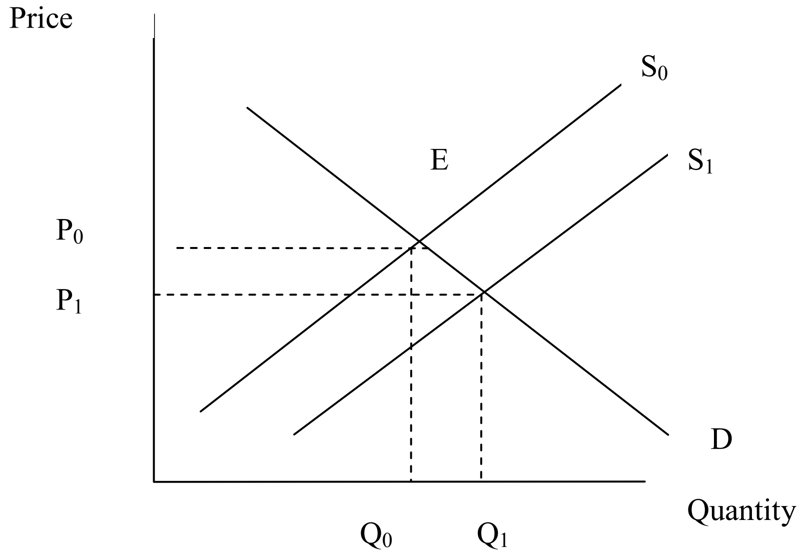


Figure 2.3 The competitive market equilibrium (Source: Brown & Campbell, 2003)

If there is a positive net present value (NPV) it indicates that there are greater benefits than costs and the gainers can then potentially compensate those who lose and still be better off. Such a compensation test indicates the project's ability to allocate resources in an economically efficient way. A CBA calculates all the benefits and costs regardless of the winners and losers and tells weather the investment is an efficient use of resources. The distributional effects are ignored initially but can also be calculated as discussed in section 2.4. The projects that drive the economy forward are meant to be chosen. (Perman, 2003)

2.2.1.1 Net present value of an investment (NPV)

The *net present value* (NPV) is the aggregated value today of a series of cash flows occurring in the future. It is calculated in today's monetary value in order to make future incomes comparable with incomes from other potential projects. The annual net cash flows over the investment's life need to be estimated. It needs however to be considered that one unit today accounts for 1 plus the interest rate next year (1+i). In the discounting process future incomes therefore needs to be taken back to the starting point by dividing the next year amounts with (1+r). This signifies that the higher the interest rate used is the lower is the value of future payments. (Brown & Campbell, 2003) The discount rate where the NPV equals 0 is called the *internal rate of return* (IRR). IRR is another test for project appraisal and whether it should be undertaken or not. The IRR value can help decision makers to compare investments to given cost of finance and if the IRR is greater than the rate of interest a project should be undertaken. (Perman, 2003)

2.3 How to make a CBA

When a CBA approach is used to evaluate an investment, it is important to map out how the situation would be both with and without the investment and to estimate the difference the project makes. The benefits and costs that occur throughout the whole duration of a project, and that would not have occurred in the without scenario, should be listed. This is both the ones that have a market value and those that have not. One way of doing this is to start off with a company's financial situation and then broadened this to also include social costs and benefits that are involved with the investment and that would not have occurred without the project. This is done through the shadow pricing and the valuation of externalities. The net result of this in monetary terms is then used to calculate the social NPV. (Brown & Campbell, 2003) When the total net benefits of a project have been calculated the decision maker has an idea whether the project is an efficient or inefficient use of resources. The total value of all net benefits has then been aggregated, regardless of who gain from these benefits. (Brent, 1997)

First it however has to be decided from whose perspective the costs and benefits are to be calculated; which groups of people or which geographical area are to be considered when making the analysis. It is referred to as the reference group and it is often the residents of a country but it can also be a much narrower definition dependent of the aim of the analysis. The groups that fall outside this are referred to as a part of the non-reference group. The application of this theory and the method used to carry the analysis through in this research is further explained in the methodology chapter three, section 3.1. (Brown & Campbell, 2003)

2.3.1 Estimation of shadow prices from existing market prices

As discussed in 2.2.1 the prices for inputs and outputs have to be adjusted in order to mirror a pure competitive market. Here some examples of how this is dealt with are presented. In the presence of distortionary taxes the prices should be set to the before tax level in a CBA. These taxes have the purpose to collect revenue for the government and not to address external problems as pigouvian taxes are intended to do. (Perman 2003) Since the CO_2 in this thesis are evaluated according to scientific evaluation models the pigouvian Swedish CO_2 tax has been deducted together with the distortionary energy tax. This has been done in order to evaluate the damage that these emissions do to the environment in the most accurate way.

In the case of labour it is slightly more difficult to assess the shadow price. Considerations need to be made if the labour is already employed or if it is unemployed. If the unemployment rate in a society is high the opportunity cost of the labour will be low since the labour equilibrium has been reached and bypassed in the economy. This means that if there are no alternative employment opportunities more benefits can be accounted to the project. (Brown & Campbell, 2003) The salary that an employee receives after tax does not reflect the total contribution to the society. The total salary, taxes included, does instead measure the marginal contribution to the output from one unit of labour. Via the income tax the total contribution is shared between labours (the after tax wage) and the government (the income tax) and therefore the opportunity cost of labour would be underestimated if the net of tax was to be used in the CBA. This is why gross wages are used later on in the analysis. (Brown & Campbell, 2003, Brent, 1997)

2.3.2 How to consider external costs and benefits in a CBA

Significant positive and negative externalities in the project, not captured by market prices, should also be valued and accounted for in the CBA as argued in the 2.2.1. Bioethanol production has the potential to reduce the level of CO_2 emissions from the transport sector. The usages of biofuels also have a potential to reduce the total dependency of fossil fuels and can contribute with other external effects such as an open landscape. This is potential benefits that have to be taken into account when making a CBA. Whereas shadow pricing was about adjusting the existing market price these occurrence has not been captured by and valued at a market. (Brown & Campbell, 2003) Since there are no existing values one has to estimate the marginal value of negative and positive externalities through non-market valuation methods in order to understand what effect the project is causing if it is carried through. In this research the benefit of CO_2 reduction has been taken into account (this will be discussed in section 2.5). Other external benefits and cost have however not been considered due to time constraints and lack of comprehensive information. (Perman, 2003)

2.3.3 What discount rate to be used in the CBA

As discussed in 2.2.1.1 the level of interest rate used when discounting is important for the outcome of the CBA. The interest rate reflects the time preference, the willingness for individuals in the society to give up consumption today for consumption in the future. (Brown & Campbell, 2003) Since a person doesn't live forever the distant future is of less importance than the near future. Table 2.1 below, taken from Perman (2003), shows the NPV of £100 at different discount rates. It is shown that the choice of discount rate can change the NPV of an investment considerably and it also shows that the project time also is an essential factor. (Perman, 2003)

The effect of the discount rate and the time period

	Number of years			
	25	50	100	200
Discount %				
2	60,95	37,15	13,80	1,91
4	37,51	14,07	,98	0,04
6	23,30	5,43	0,29	0,0009
8	14,60	2,13	0,05	0,00002

Table 2.1 The importance of the discount rate and time period for an investment's NPV (Source: Perman, 2003)

When evaluating a project's profitability from a social perspective it is common to choose a discount rate that is in level with the interest on government bonds. It is then important to choose a security that has about the same time to maturity as the investment. If the life time of a project is 10 years for example it is advisable to choose the interest rate of a bond with 10 year existing life time. There is further a universal agreement over the world by economist that real rates should be used and not nominal rates. Therefore this market interest rate should be subtracted by inflation. (Brown & Campbell, 2003) When evaluating the investment in the case study in this thesis such a discount rate is therefore chosen. This rate is taken from bonds with 15 years to maturity, found at the Swedish National Dept Office. This figure is 1.8% in real terms. (Swedish national dept office, 2006)

2.4 Distributional effects of the aggregated value

In order to understand whether it is favourable to invest in bioethanol production it is also important to identify potential winners and losers. The benefit change caused by the project for different stakeholder thereby has to be estimated. Even if a project in total is inefficient it can be undertaken dependent of the goal of the society. These distributional effects are essential for the decision makers and the values estimated by different sub-groups therefore has to be identified, calculated and aggregated. (Brent, 1997) The reason is that the government sometimes prioritises some groups in the society more than other groups. If for example the benefit for the unemployed and the domestic bank is the same the value created for the unemployed group might be more important to support for the society even though it is the same value. Without the distributional effects one is making an economic rather than a social evaluation. (Brown & Campbell, 2003)

One way to identify the benefits to the reference group is to follow the tax and financial flows generated by a project. These flows distribute net benefits between the private and public stakeholders; some are included in the reference group and some might not be included. Transfers, flows of money that does not add value to the economy but moves benefits around, are not relevant when estimating the economic efficiency of a project but are however important then distributional effects are being estimated. It is important to know whether benefits are being transferred from a reference group to a non-reference group or to other members of the reference group. (Brown & Campbell, 2003) This is all considered in section 4.3 when the distributional effects of SvL's bioethanol factory are estimated. The shadow prices are another source of information about the distribution of benefits to different groups. Here the differences between the market price and the shadow price of inputs and outputs may represent cost and benefits received by members of the reference group. If the market price of an input is higher than the estimated shadow price a benefit exists. If the shadow price on the other hand is higher than the market prise the opposite there is a loss of profit. The opposite relation is valid regarding outputs. (Brown & Campbell, 2003)

2.5 What is the value of the reduced carbon emissions?

Reduction of CO_2 is as discussed in 2.1.2 a driver for increased production of biofuels around the world. The amount of reduction and the value per unit is therefore of large interest when evaluating whether investments in biofuels production is an efficient usage of resources. In this thesis an attempt is made, as is mentioned in 2.3.1, to evaluate the environmental damage that CO_2 is causing in the most accurate way. Therefore the scientific research in this area is reviewed properly. There are however arguments between scientists regarding the actual cost for emitting CO_2 emissions, which will be discussed below.

2.5.1 Social cost of carbon

Social cost of carbon (SCC) is a monetary indicator of the global damage caused by one extra ton of carbon emitted today and it is employed to calculate the financial value of the marginal damage avoided by reducing 1 ton CO_2. The SCC is expressed in value/tC, where 1tC=3,664tCO_2. (SEI, 2005) The estimated value for the SCC is in other words the benefit that should be used in the CBA when calculating the aggregated value for the project of biofuels production. The CO_2 saved by whole project should then be multiplied with the SCC to get the aggregated benefit (ibid) It is however not consensus among scientist how to put a value on this, the SCC is dependent on range of assumptions taken. There are different opinions about which areas to include when assessing the future damage of CO_2 emissions, how to estimate the costs and how to discount these cost to today's monetary value. Different assumptions can radically change this figure. (Clarkson & Deyes, 2002, Weitzman, 1998, Tol, 2005, SEI, 2005)

As shown in 2.3.3 the choice of discount rate can make a large difference when valuating benefits and costs that occur in a distant future. The higher discount rate used the lower the value for future damages today and vice versa. (Clarkson & Deyes, 2002) Different studies use different methods for discounting. Weitzman (1998) and Tol (2005), among many other scientists, argue that since climate change has a very long time perspective this should also be treated with low discount rates. (Weitzman, 1998, Tol, 2005) One option is to use declining discount rates over time, thus the discount rate used is lowered gradually as time goes by. (Weitzman, 1998) This is a rather new development and is, even thought it is not an ad hoc solution, supported both empirically and theoretically. Table 2.2 illustrates the declining discount scheme, referred to as the Green Book Scheme that the UK HM treasury has published and are planning to use for social investments. The green book schemes are used in the FUND model for estimation of the SCC and are therefore introduced below. (Swedish EPA, 2005)

The Green book discounting scheme

Year	Discount rate
1-30	3.5%
31-75	3.0%
76-125	2.5%
126-200	2.0%
201-300	1.5%
300-	1.0%

Table 2.2 The Green book scheme-HM treasury's declining discount rates (Source: Swedish EPA, 2005, Guo et al 2006)

Equity weighting (EW) is also something that also is debated among scientists. This concept refers to correction of relative incomes in-between countries so that a life in a poor country is valued to the same monetary value as a life in a rich country. (Clarkson & Deyes, 2002, SEI, 2005) However, according to Tol (2005) this concept mirrors an idealized world even thought it theoretically is sound. He argues further that in reality rich people do not care as much for poor people as is accounted for in the computer models. (Tol, 2005)

2.5.1.1 Values for SCC calculated in different studies

There is a large insecurity about how much it actually costs to emit a ton of carbon today. There are arguments that very few of the existing studies cover any non-market damages and that most of the available studies contain uncertainties also in the damages that are incorporated in the calculations. AEA (2005) Below follows a description of existing studies of the value of SCC and their results.

The FUND model (Climate Framework for Uncertainty Negotiation and Distribution) is a complex integrated assessment model that predicts the future and estimates a value of the damage from climate change in various sectors. It was established in the late 1990s in order to estimate the global impacts of greenhouse gas emissions. (Guo et al 2006) The EU, thought the ExternE research project, has used this model to estimate the marginal abatement cost for carbon emissions. (Krewitt, W., 2002, NewExt, 2004) This model evolves over time; it is continuously updated and improved. The latest version FUND 2.8 runs from year 1950-2300 and it divides the world into 16 geographical regions and covers a range of areas for which the net effects are estimated (Appendix 1 covers this in more details). About economic and population growths and forecasts about CO_2 emissions are made for each region individually and are then simulated globally. (SEI, 2006) The value for SCC is given by running the model with and without an additional ton of carbon. The marginal damages per region per year are discounted back to present values. (Guo et al, 2006) As shown below the FUND model provides a large range of values for SCC and the distribution of results are widely spread, from -£1-£1375. The average valued calculated with the Green book discounting and EW £63 is however considered as a relevant value for SCC. (SEI, 2006)

The FUND model and estimated SCC under different assumptions taken

	Reference		Average		Standard deviation	
	EW	No EW	EW	No EW	EW	No EW
Green Book	£20	£19	£63	£24	£314	£165
PRTP=0%	£728	£56	£815	£171	£1,375	£671
PRTP=1%	£174	£11	£429	£43	£1,221	£240
PRTP=3%	-£1	-£2	£40	-£1	£434	£165

Table notes: EW = Equity weighting based on per capita income; No EW = no equity weighting
Median is the 50% value. Reference is the single run with 'best guess' of FUND parameters. Average is the arithmetic average (or median).

Figure: 2.4 Summary of FUND results (£ in 2000 price level) (SEI, 2005)

The PAGE model is another integrated assessment model. The latest version, PAGE2002, is an updated version. (Albert & Hopes, 2006) It uses rather simple equations to capture complex climatic and economic phenomena. The PAGE model gives estimates in a range from £0 to over £400. The mean value (with the green book discounting scheme and equity weighting) is set at £46 for 2000 with an increase over time. The page model includes some but not all major climatic effects but exclude any socially contingent effects. (AEA, 2005)

Clarkson & Deyes (2002) reviewed nine major studies within a range of £35-140 and came up with a recommendation that £70 /tC should be used, with a £1 increase annually. (Clarkson & Deyes, 2002) Pearce reviewed Clarkson & Deyes and argued that this was a too high estimate and argued that £3-15/tC is more relevant value with equity weighting and between £4-27 if time varying discount rates are used. (SEI, 2006) AEA (2005) is also arguing that £70 is high comparing to other studies with normal assumptions about discount rate and aggregation. (AEA, 2005) In an attempt to establish more correct standard value SEI (2005) together with AEA (2005) reviewed existing studies and came to the conclusion that there is a large uncertainty about what value that should be used but both argued that £70, recommended by Clarkson & Deyes (2002) is a to high estimate. They argued that the SCC has a large uncertainty and could be set at a very high level but argued further that £35 is a reasonable benchmark. (AEA, 2005, SEI, 2005)

Guo et al (2006) used various declining discounting schemes in the FUND model. They came to the conclusion that it is unlikely that the SCC will be as high as £70. Only with one of the schemes tested the SCC exceeded £70, under the other schemes the estimated value was much lower. (Guo et al, 2006) Tol (2005) made a literature review over 103 existing studies, authored by 18 independent teams of scientists. He found a wide range of estimates of the valuation of the SCC, largely because these studies had been carried out under different assumptions and methods. Tol argues that the studies that have been undertaken vary because different studies assume different climate scenarios, make different assumptions about adaptation and include different impacts. They also vary because some studies use a constant discount rate whereas others use a variant of a declining discount rate schemes. Further, some of them considered equity weighting and some of them did not. The 103 studies were in a range between £1-186. Tol (2005) argues however that it is unlikely that the SCC will exceed £27 and that it is likely to be considerablylower.

Summary of the findings about the SCC in the studies reviewed

	Value of SCC	£/tCO_2	SEK/tCO_2
Clarkson & Deyes, 2002	£70	£19	265
Tol, 2005	£27	£5	69
Pearce	£3	£1	14
PAGE	£46	£13	174
AEA, SEI	£35	£10	132
Guo et al	£70	£19	265
FUND (mean)	£63	£17	238
1tC=3,664tCO_2 **£=13.86 SEK**			

Figure 2.5 The SCC according to different studies and the translation into cost per ton CO_2 emissions

2.6 Chapter findings

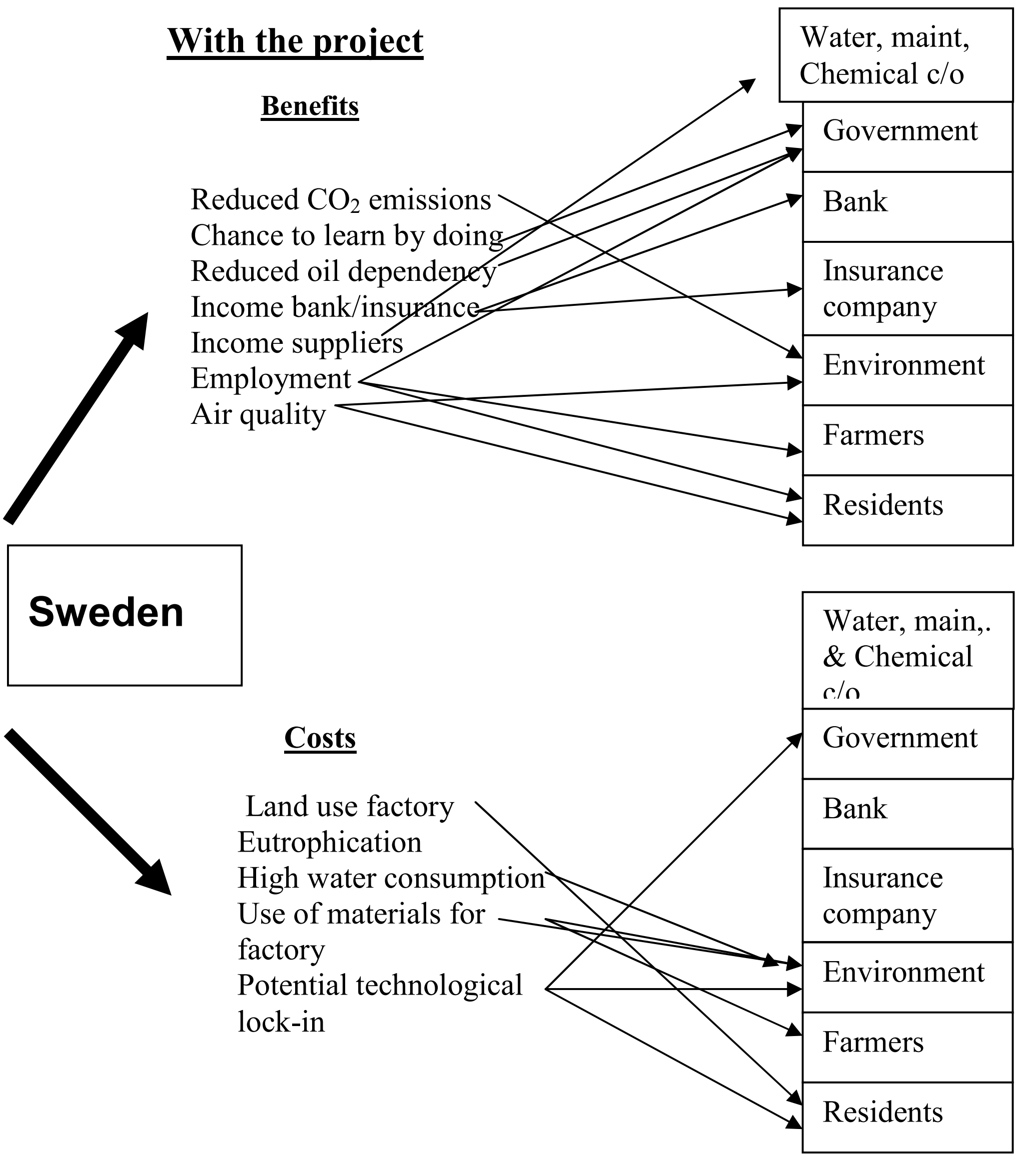
In chapter 2 important information and tools about how to carry through the research in chapter 4 has been provided. The most important conclusions are here given in bullet points.

- If a projects is evaluated by a CBA it is important to first state an objective and identify the reference group that is to be calculated for. This is often the residents of a country but it can also be much narrower than that.
- The "*with and without* "the investment scenario has to be identified. All cost and benefits that would not have happened without the project should be listed. When calculating the social value of an investment the market price for inputs and outputs used has to be adjusted for in order to mirror a competitive market. Also positive and negative externalities should be evaluated and listed here.
- CO_2 reduction is one main driver for investment in biofuels production. The cost to emit an extra ton of carbon today, the SCC, and the level of reduction is therefore important when evaluating an investment. The level of the SCC is however something that doesn't have a consensus among scientists and there are a range of values available from different studies under varying assumptions.
- The level of the discount rate that is chosen to calculate the NPV of an investment is important for the outcome. Usage of a high discount rate put less value on incomes and costs that occur in a distant future.

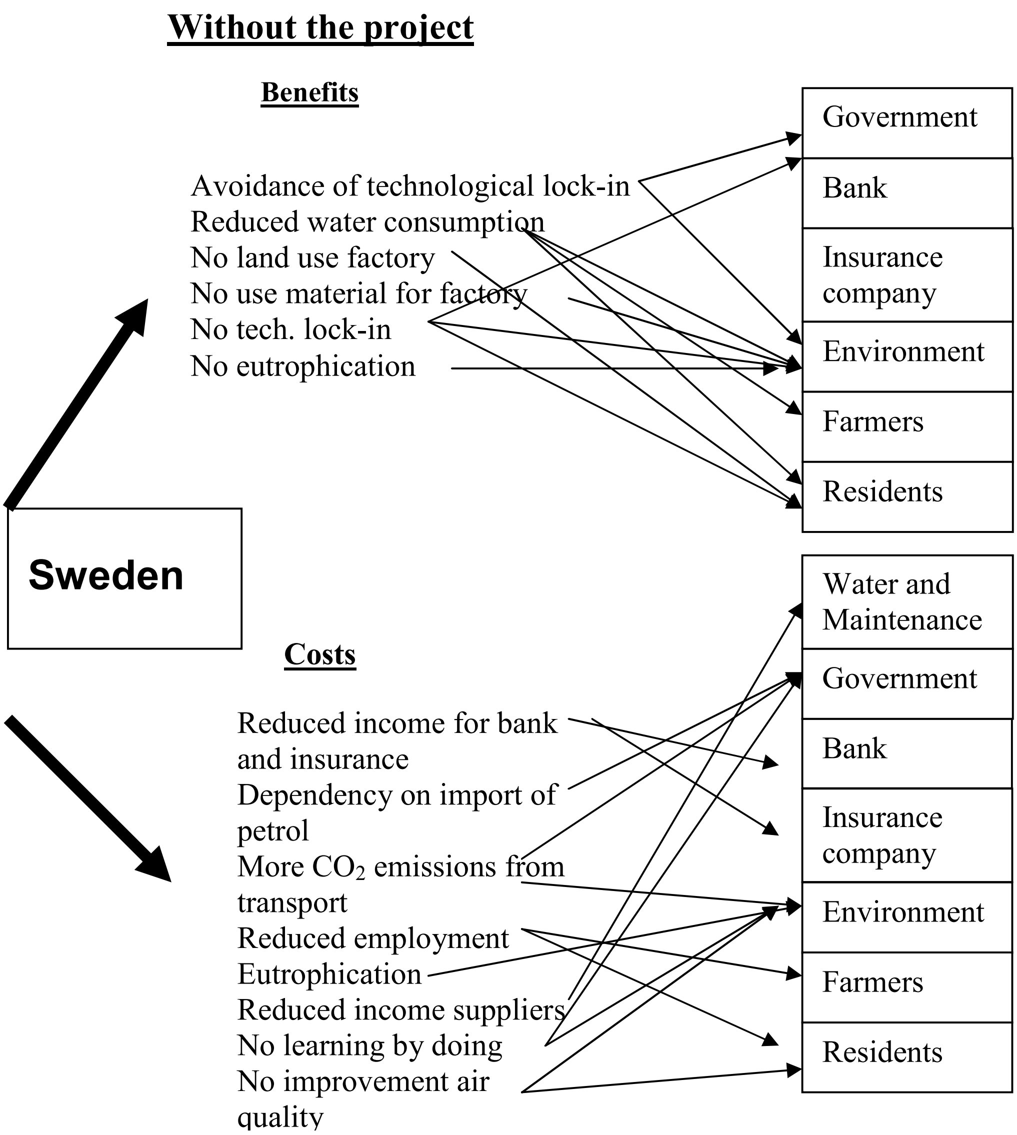
2.7 The conceptual framework

The finding in the chapter 2 results in a conceptual framework that reflects the "with" and "without" situation for an investment in bioethanol production in Sweden. The potential benefits and costs are mapped out for Sweden as the reference group.

2.7.1 The situation with an investment



2.7.2 The situation without the project



These maps present areas that potentially are affected by an investment in bioethanol production. The level of influence is however dependent on the assumptions taken in the research. Due to time constraints and lack of information not all these cost and benefits are evaluated in the research. The assumptions taken for this will be discussed in chapter three.

CHAPTER 3

METHODOLOGY

This chapter is concerned with the methodology used for answering the aims, objectives and research questions. A case study approach where chosen for this thesis and quantitative data where collected for use in a fixed design study using CBA methodology for valuing inputs and outputs for the studied project. Below will the general research strategy and the type of data be described, moreover will how the data where collected and analysed plus how conclusions where derived be presented.

3.1 The research strategy

Robson (2002) referrers to research strategy as the general approach taken during an enquiry, there are several different approaches to choose from but basically a study can be either fixed or flexible design depending on what is studied and if qualitative or quantitative data is used. This is a fixed design study since it is relying on the methodology of the CBA analysis. A CBA uses quantitative data when the purpose of the analysis is to look at the net benefits of an undertaken project and numerically calculate those and come up with a final monetary value. The study has been carried out as a case study because of the good fit with Robson's (2002) case study criteria of being a project selecting a single organisation to study, a study of the organisation in its context and collection of data via site visits and documentary analysis.

In Sweden the only large scale production facility of bioethanol is owned by Svenska Lantmännen (SvL). In order to evaluate domestic bioethanol production this company and its production method has therefore been studied. SvL uses cereals for its bioethanol production, which is also a commonly used method in the rest of the EU.

As discussed in section 2.3 it has to be stated from whose perspective the calculations are made and therefore a so-called reference group has to be identified. The reference group chosen in this case study is Sweden and therefore stakeholders outside Sweden can be referred to as the non-reference group. SvL is, as discussed in 2.3, not to be considered a part of the reference group. The reason for choosing Sweden as the reference group is due to this country has the largest consumption per capita in Europe and is therefore an interesting research area. (Brown & Campbell, 2003)

The research scenario studied is based on a range of assumptions that will be reported and discussed below. The investment is calculated for 15 years and this is used since this is the expected life time for the machinery used in the process. Further the scenario researched is based upon the fact that the bioethanol factory is surrounded by one of the largest flat countries in Sweden with fertile soil that has been used as agricultural land since the Viking age. It is likely to think that this land would be used for similar production even if there would be no production of bioethanol. In this research it is therefore assumed that all land that is used for bioethanol production would also in the without the project scenario be used for cereal production, either for animal feed or for human food production. This signifies that the inputs and outputs from the cultivation of wheat then can be assumed to would have been used even without the bioethanol factory.

It is assumed that the cultivation of the wheat for human food production and animal feed is produced in the same way as the wheat for bioethanol production regarding inputs such as the usage of fertilizer, chemicals, tractor usage, drying of the wheat etc. Since this is assumed to have happened even without bioethanol production the cultivation phase of wheat is therefore not considered in this analysis. To sell the wheat it will also be assumed that farmers would have had to transport the wheat the same distance also if the cereals were for bread or animal feed purpose. There will however be a discussion of how changes in these assumptions would change the outcome of the research. Regarding the environmental analysis this study focuses only on the CO_2 equivalent emissions. This means that other types of emissions are ignored in this research. The most important reason for this is that climate change one of the most important environmental issues in facing the world today. Since the biofuel directive is promoting introduction of biofuels it is important to evaluate the effect on CO_2 reduction. This is also a way to limit the study to be a feasible analysis for an MSc thesis.

The research is divided into several stages of calculations that all build on each other. Five main spreadsheets are used, all linked to each other. All key information about SvL is provided in table 1 of the spreadsheet (See appendix A2) and includes operation costs, revenues, fixed investment, interest rate, depreciation cost and the financing for the SvL. This information about SvL is then the base upon which the social CBA is made. Figure 3.1 show how the spreadsheet is constructed and is shown to give the reader an understanding of how the CBA excel model looks like. The analysis starts off with a financial appraisal for the investment in bioethanol production. This is all to calculate the net present value, the internal rate of return and monitor financial flows and the company tax paid by SvL. This is further shown in appendices A6 and A7.

This provided information about SvL is then broadened in order to reflect the social costs for the inputs and outputs. This means that taxes, subsidies and externalities are adjusted for. In figure 3.1 these new shadow adjusted prices are presented in the shadowed area. These values are then used for calculations under the sheet social CBA (presented in appendix A11) which feeds the development of a social CBA where the total aggregated social NPV is calculated. The social NPV includes values for both the reference group as well as the non-reference group. In order to understand the distributional effects within the reference group from this investment this analysis is developed further. The adjustments in taxes and subsidies and the financial flows are used and calculations are then done in the reference group CBA. (Presented in appendix A13) A sensitivity analysis is then made for changes in the costs for inputs and outputs.

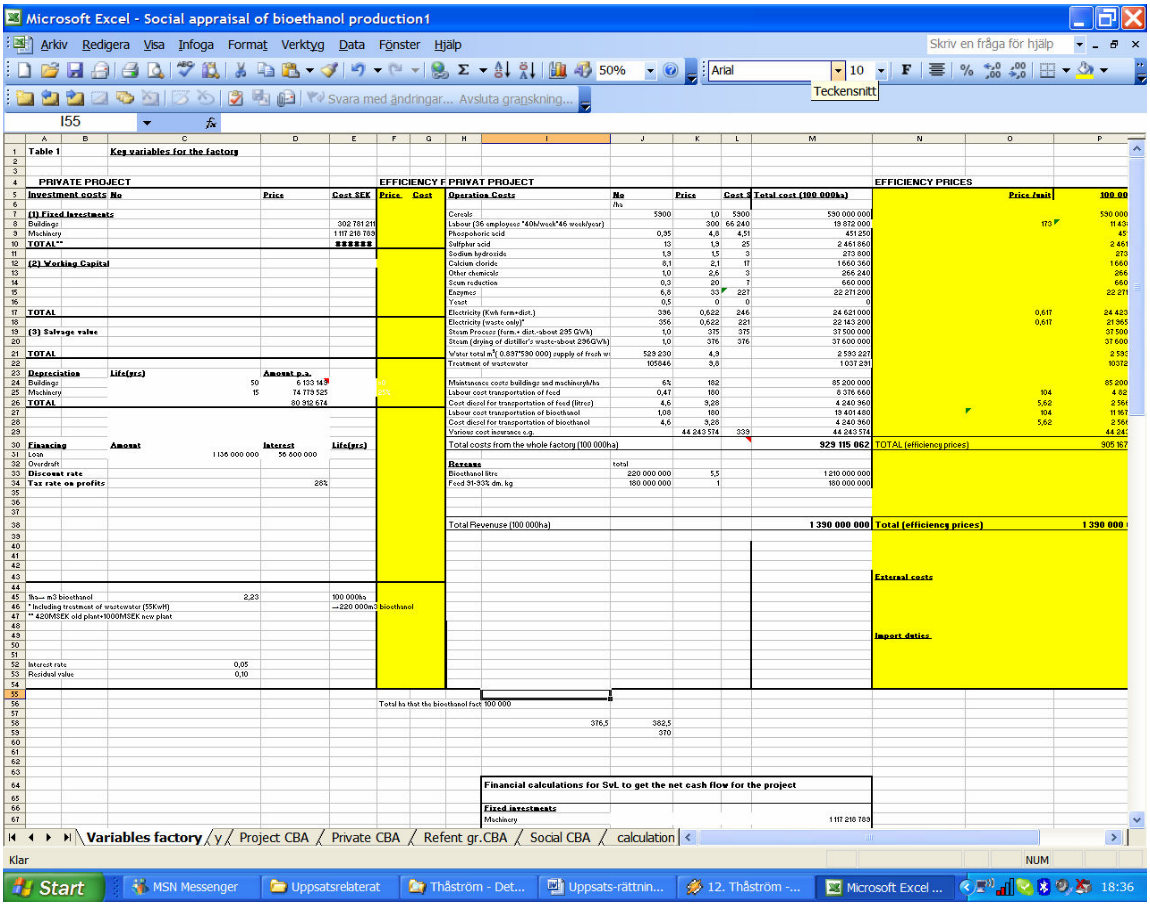


Figure 3.1 The spreadsheet with the key variables upon which all calculations in the research are based

3.2 The type of data collected

Studies are often intimately related to the data the study relies on, Quantitative (numbers) or Qualitative (words and sentences). This quote from Robson (2002) is true for this study when only quantitative data are applicable in the assessment of SvL and the net cost or net benefits associated with the organisations undertaken activities. The CBA preformed is relying exclusively on quantitative data, some collected during the site visit which have been carried out and other data has been gathered through literature review and documentary analysis. Mainly printed literature about the CBA method itself have been used for building the spread sheet model and the numerical inputs in to the spread sheet has been obtained by using company specific information, reports and LCA studies.

The assumptions made during the CBA calculation are when made clearly stated and only used when no other reliable data have been accessible.

3.3 Data Collection

Data collection can be divided in two parts, secondary data collection and primary data collection. They are both outlined below.

3.3.1 Secondary data collection

The secondary data collection has mainly been focused on the use of printed and internet sources. The data collected can be divided in to:

- The use of publications manly from libraries and private collections.
- The use of databases and the information available in those.
- The use of serious internet websites manly from governmental organisations, well renowned firms and industry organisations.

The major secondary sources chosen have been websites and reports form government organisations and well established private companies. Academic journals have also been of great help as well as economic literature in general. The sources used have all been chosen on the basis of reliability and source recognition. The secondary sources where reviewed in order to write the literature review, to gather data on CBA methodology, discounting, SCC etc. Much of the data for the chapter 4 are adapted from an extensive study to which the author has been referred for details by SvL.

3.3.2 Primary data collection

The primary data collection phase has mostly been conducted through a site visit where the Managing Director and the Purchasing Manager where met and useful data for the CBA where collected. The information which was provided was mostly concerning production cost and environmental impact of the process as well as information of the price of sold bioethanol. The tour of the site provided useful insights in the production system of bioethanol since it gave the author a better understanding of the processes and the size and volume of the inputs and outputs involved. Primary data has also been collected from the meetings with staff at SLU in Uppsala and through extensive email correspondents with researchers involved in studies of biofuels production processes in Sweden. There has been several email exchanges with the author of an extensive LCA of bioethanol produced from grains to clarify different figures needed for the CBA spread sheet.

3.4 Deriving conclusions

The data has been used to draw conclusions on the suitability of producing bioethanol from grains in Sweden. The conclusions have been formed from manly the results and the NPV's derived from the data analysis. The information in the literature revive have also been important when formalising the discussion and the conclusion when it is important to view the CBA results in light of the assumptions made.

3.5 Chapter findings

The main methodological points are as follows:

- The undertaken research is a quantitative case study of the Swedish farmer's cooperative SvL
- The method chosen is a Cost benefit analysis (CBA)
- An estimation of the social NPV and the distributional effects of bioethanol production are carried through. This is done through the construction of an excel model with five different spread sheets that all build upon each other
- It is assumed that without the project the land used for bioethanol production with the project would be used for cereal production for human food without the project
- Secondary data are collected through for usage of databases, library and websites.
- The primary data are collected during a site visit, meetings with people at SvL, telephone communication and email contacts

CHAPTER 4

FINDINGS AND DISCUSSION OF THE CASE STUDY RESEARCH

Bioethanol production under Swedish conditions and the environmental benefits that arise with replacement of fossil fuels are evaluated in this chapter. The purpose is to identify all inputs and outputs from production to consumption in the bioethanol process and value them to their real cost to society. This means that the shadow prices for inputs and outputs have to be identified. These adjusted figures are then used in the Cost-benefit analysis (CBA) in order to get an aggregated value as well as the distributional effects for separate groups within the society. In order to evaluate domestic bioethanol production and to be able to put a value of this "project" an individual company is used as a case study. The Swedish farmer's cooperation is used as a case study throughout this entire chapter. It therefore starts off with identification of inputs and outputs in the bioethanol factory and their cost and revenues. These values are then adjusted to mirror a social perspective of the investment in bioethanol in Sweden. All values are calculated in SEK, Swedish kronor. The exchange rate used is 1£= 13.86 SEK and the prices are all without VAT since this tax is a consumer tax and is in reality not a cost for companies (Swedish tax agency, 2006)

4.1 The private NPV from the production of bioethanol

This section starts off by mapping out the inputs and outputs and valuation of these from SvL's bioethanol factory. This process reflects the change that this investment in bioethanol production makes, that would not have happened without SvL's bioethanol factory. This makes it possible to calculate the investment's NPV for SvL. This value is then used in section 4.2 and 4.3 when the social value of this investment is evaluated.

4.1.1 The process in SvL's bioethanol factory

Figure 4.1 below illustrates the production process of bioethanol in SvL's factory that is presented in order for the reader to get an overview over how SvL's factory functions. The grain arrives and is stored in the grain silos before the *milling* process. After the milling water and enzymes is added to the grain to porridge like consistence in the *Liquification* process. In this step the starch in the grain is broken down and transformed to sugar. Yeast is then added to the sweet liquid during the *fermentation* process. During this step the sugar is transformed to CO_2 and a liquid with about 15% alcohol content. To purify this liquid it has to be *distilled* in a two step process which results in bioethanol with close to 100% alcohol. (Pers.com, Beckman 2006) The distiller's waste from this process, which is about 1/3 of the initial grain, is dried and sold as feed to animals as a substitute to Soya. This is an energy demanding process that requires about 50% of the total energy (see the square in figure 4.1)

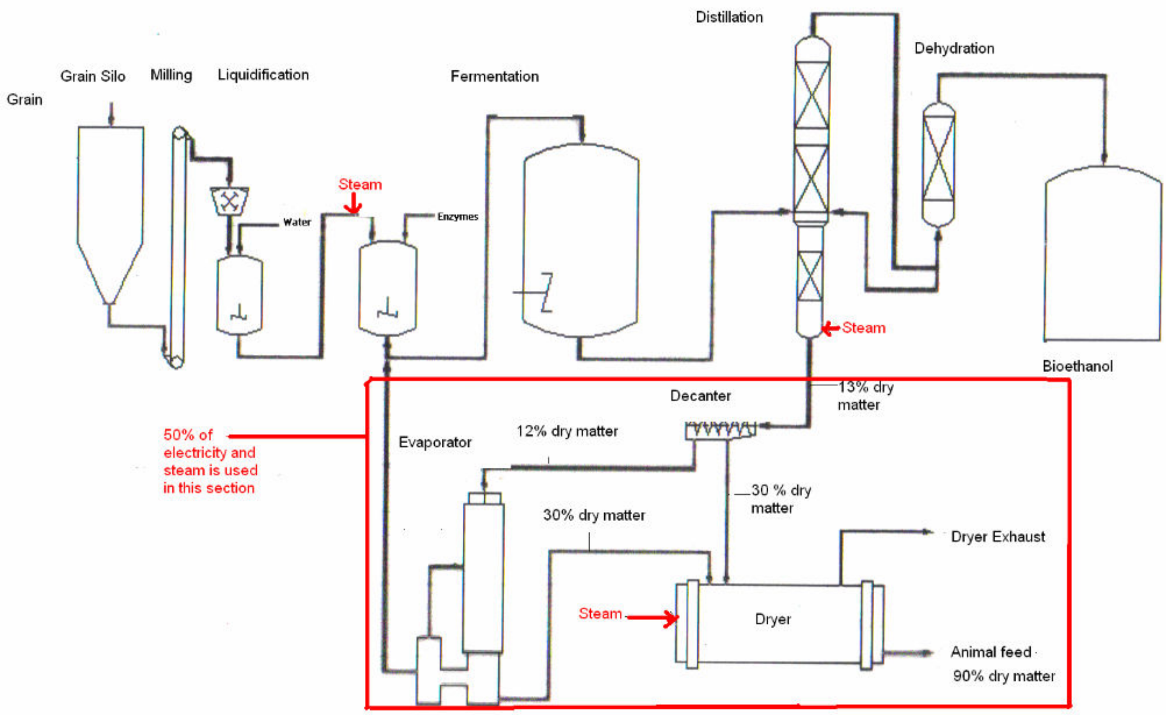


Figure 4.1 Explanation of the production process of SvL's bioethanol factory (Source: SvL, 2006)

Outputs

Outputs from bioethanol factory

Bioethanol 220 000 m^3
Feed 180 000 tonnes
Waste water 106 000m^3
CO_2 equiv: 13 900 tonnes
(67% of total emissions in the process)

Outputs from transport
Outputs
Employment

CO_2 equiv: 2800 tonnes
(33% of total emissions in the process)

Output from bioethanol production

Reduced oil dependency*

322 000 tonne net reduction -CO_2 emissions.

Inputs

Inputs in the bioethanol factory
Investment cost 1 420 000 000

Grain	590 000 t.
Steam	587 GWh
Electricity	77 GWh
Water	530 000 m^3
Labour	66 240 h
Chemicals**	

Energy Input: 663 000 GJ *(87% of total energy input in the process)*

Inputs for transport

Diesel for the lorry	914 m^3
Labour	154 000 h

Energy Input: 41 000 GJ *(13% of total energy input in the process)*

Bioethanol consumption

220 000 m^3 bioethanol (substitutes 144 000 m^3 petrol)

180 000 tonnes animal feed (substitutes 180 000 tonnes Soya)

The bioethanol plant

Transport of bioethanol and feed

Usage of bioethanol and feed

Total input
Total Energy input: 704 000 GJ
Total CO_2 equiv: 16 700 tonnes

* Has not been quantified in monetary terms in this study
** CO_2 emissions only have been accounted for.

Table 4.1 Identified inputs and outputs used in production process of bioethanol from cereals.

4.1.2 *Input and output from bioethanol produced from grains and the cost and revenues for SvL*

In table 4.1 the main inputs and outputs in the production process of bioethanol is described and aggregated for the whole factory during one year. This is adapted from the total raw material used for production of 220 000 m^3 bioethanol and 180 000 tonnes animal feed which will be the level of production in SvL's new bioethanol factory. Currently the production is only about ¼ of this but since SvL has decided to invest in a factory with the above capacity during 2008 this level of production is used instead of the current level (Pers. Comm. Beckman) According to Bernesson (2004) the average harvest in this area is about 5900kg/ha (dried wheat, 14% water) and this thereby signify that about 100 000 ha land is used to produce wheat for bioethanol production in SvL's factory (ha=10 000m^2, 100 000 ha equals 247 105 acres).This analysis covers the main inputs and outputs in the factory and during the transportation of the finished bioethanol and animal feed. The assumptions made are discussed below.

4.1.2.1 The bioethanol factory

The total investment costs for buildings and machinery is 1 420 million SEK. (Pers. Comment, Werling, 2006, Bernesson, 2004) According to Bernesson it is reasonable to assume that the machinery constitutes 79% and the buildings 21% of this investment cost and that it can be used for is 15 respectively 50 years. The cost for maintenance of buildings and machinery is assumed to be 6% of the total investment cost annually. (Bernesson, 2004) It is here assumed that 80% of this borrowed at a bank to 5% interest rate and that the rest is SvL's own capital. According to Beckman (2006) 2650kg wheat is used per m^3 bioethanol which means that about 590 000 tonnes cereals will be needed for the total production. The price for cereals is 1 SEK/kg. (Pers.com, Beckman 2006)

The electricity is assumed to be the average Swedish electricity which is a mainly hydro and nuclear power (See Appendix A3.2) (Bernesson, 2004) and the steam is assumed to be produced from biomass and provided by a large energy producer located just next to the bioethanol plant (Pers.com, Beckman 2006). The energy consumed for production of bioethanol and to dry the animal feed is calculated to be 0.13 MWh electricity and 995 MWh steam per tonne wheat processed. (Bernesson, 2004) The cost for the electricity used is 0.622 SEK/KWh and 0.13 SEK/MWh for the purchased steam. The energy markets are however currently fluctuating in the world. It is therefore possible that this price for the energy is underestimating the true cost. Therefore the result will be tested for a 20% increase in energy prices. The water requirement is calculated after that 0.9 m^3 water is needed per tonne wheat and that 20% of this water has to be treated as wastewater whereas the rest evaporates during the production process. The price for water supply is 4.90 SEK/m^3 and the price for treatment is 9.18 SEK/m^3 (Norrkoping Water, 2005, Pers. Comment Kindegard, 2006)

The labour cost used adapted from Bernesson (2004) is 180 SEK/h for cultivation and transport and 300 SEK/h in the factory. This goes in line with the averagely level of salaries in Sweden in for similar employment. (SCB, 2002) Here taxes are included which are 32.28% employment tax and 32% income tax. (Swedish tax agency, 2006) The factory currently employs 18 people will, according to Beckman (2006), increase to the double 36 employees with the new factory. This then adds up to 66240 working hours per year in the factory (40h/week*46weeks/year). (Pers.com, Beckman 2006) A variety of enzymes, chemicals and yeast are also required in the process. The emissions and energy requirement for production and transportation is included in these calculations adapted from Bernesson (2004) (The chemicals and the quantities calculated for as well as data about the emission and the energy requirement for this is presented in appendix A3) Due to time and information constraints however potential negative effects other those caused by CO_2 emission is however ignored in this study. In table 4.3 there is a post for various costs. This is assumed to be 5% of the total costs and includes insurance, chemicals not listed etc. In total the factory emits about 14 000 tonnes CO_2 equiv. or 67% of total emissions. The energy input also according to these assumptions 663 000GJ. This is calculated after the assumptions taken above and covers the energy production, handling of waste water, production and consumption of chemicals and production of machinery and building material. (In appendix A3 the energy input the CO_2 emissions that is emitted during the production process is presented in more details). (Bernesson, 2004) Appendix A4 and A5 summarises presents this data by activity.

4.1.2.2 Transport of feed and finished bioethanol in Lorries

It is assumed feed that animal feed and finished bioethanol is transported 110km in Lorries that can take up to 40 tonnes. The total labour required for this is 154 000h (0.26h/tonne wheat for loading, unloading and transport) which then requires 84 yearly employment positions (40h/week*46weeks/year). For this it is assumed that 1.55 litre diesel is used per tonne wheat, including both the transport of bioethanol and animal feed. (Bernesson, 2004) The price for diesel is 9.3 SEK/litre. (SPI, 2006a) It is assumed that 2.7kg CO_2 emission equivalent is emitted per litre diesel. (See appendix A3.3*)* This is including production of diesel and lubrication oil which is assumed to constitute about 4.5 % of the total CO_2 emissions and 8% of the energy input in diesel production. Around 13% of total energy input in the bioethanol production is used during transport. The total transport of bioethanol and feed from the factory contributes with 7000 tonnes CO_2 of 33% of the total emissions. (Bernesson, 2004)

4.1.2.3 Consumption of bioethanol and animal feed

Since bioethanol has about 65% the energy content from petrol (EC, 2004a) the total production of bioethanol substitutes 144 000 m^3petrol. If petrol was used 340 000 tonnes of CO_2 emissions would be emitted during the combustion (2.36kg/l petrol) and production of this petrol. (SPI, 2006b) Also 180 000 tonnes animal feed is produced which can substitute Soya is produced annually (Pers.com, Beckman 2006). The substitution of petrol leads to a reduction of dependency of oil from other countries According to Hunt et al, (2004) among others however; this is a rather complex issue to measure in monetary terms. The price per litre sold bioethanol is 5.5 SEK and the animal feed is sold to. farmers for 1SEK/kg. (Pers.com, Beckman 2006)

4.1.2.4 Private Costs and Revenues for SvL

Here a compilation of the information discussed in section 4.1.2. These data are provided in order calculate the NPV and IRR from SvL's perspective. The market price for the inputs and outputs from the process are listed and an annual net cash flow is given. The total operating costs illustrates the aggregated market price for the inputs that SvL is using in the production of bioethanol. The total revenue show the aggregated revenue for SvL and the investment cost is the total investment in machinery and buildings.

Financial calculations for SvL to get the net cash flow for the project

Fixed investments			
Machinery			1,117,218,789
Buildings			302,781,211
Total investment			**1,420,000,000**
Operation Costs	**Units**	**SEK/unit**	**Total cost**
Cereals kg	590,000,000	1	590,000,000
Labour (36 employees *40h/week*46 week/year)	66,240	300	19,872,000
Chemicals, enzymes, yeast			28,044,710
Electricity KWh (fermentation & distillation)	39,583,601	0.622	24,621,000
Electricity (animal feed)	35,600,000	0.622	22,143,200
Steam Process MWh (fermentation & distillation)	293,800,000	0.13	37,500,000
Steam (animal feed)	293,100,000	0.13	37,600,000
Water total m^3 supply of fresh water	529,230	4.9	2,593,227
Treatment of wastewater	105,846	9.8	1,037,291
Labour cost transportation (feed and bioethanol)	154,323	180	27,778,140
Cost for diesel for transportation	914,000	9.3	8,481,920
Maintenance building and machinery (6%)			85,200,000
Various costs e.g. insurance			44,243,574
Total operation costs			**929,115,062**
Revenues	**Units**	**SEK/unit**	**Total revenues**
Bioethanol 220 000 m^3	220,000,000	5.5	1,210,000,000
Feed	180,000,000	1	180,000,000
Total revenues			**1,390,000,000**
Net cash flow (revenues-costs)			**460,884,938**

Table 4.2 The estimated total operation costs, revenues and fixed investment in buildings and machinery for SvL at market prices.

As discussed above this data is provided in order to calculate the NPV and the IRR for SvL which then will be the social NPV and IRR which is calculated in section 4.2. With the assumptions discuss above the net cash flows, the revenues subtracted by the operation costs plus the fixed investment for the first year, are as shown in table 4.2 about 460,000 millions SEK per annum over the period. It is assumed that the project's life time is 15 years. This assumption has been taken from the depreciation time of machinery considered in 4.1.2.1. It is assumed that the building has no value after this time either (even thought its depreciation time is 50 years) if no further re-investments are carried through because of the building's specific type. The net cash flow over this 15 year period is discounted, as explained in 2.2.1.1, into today's monetary value. (Appendix A6 shows how the spreadsheet is set up)Four different discount rates are used tin order to be able to see the difference. The total aggregated NPV for SvL for the total production is then calculated to have an IRR of 32%.

Table 4.3 shows SvL's NPV of the investment after usage of different discount rates. If 10% discount rate for example is used the investment is worth about 2,085 million SEK for SvL. This result is however rather sensitive to changes in the input and output prices. It is shown that if the price paid for bioethanol would fall by 20% the IRR would drop to 13%. Also the sensitivity for a 20% increase in the cost for energy and cereals were tested. It is there shown that the IRR would drop to 30% and 23% respectively (assuming everything else equal). This is all presented and explained further in appendix A7.

NPV and IRR for SvL for production of bioethanol				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	4,592	3,364	2,086	1,275
IRR	32%			

Table 4.3 The NPV and IRR calculated from the data provided in table 4.2 (million SEK)

From the provided information about total revenues and operating cost the company tax paid is estimated. The rate of the company tax is 28% in Sweden. (Swedish tax agency, 2006) This value is important when calculating the distributional effects in section 4.3. It is however not to be included when calculating the social NPV in section 4.2.3 since this tax is a transfer payment and does not contribute the growth of the economy. As shown in appendix A8 also the cost for depreciation of machinery and buildings and the cost for interest rate paid on loans also need to be known to calculate this. The annuity method is used to calculate the annual capital cost for machinery and buildings. (Explained further in appendix A9)

4.2 The social NPV from production of bioethanol

In this section the data provided in section 4.1 is adjusted in order to calculate a social aggregated value for SvL's investment in bioethanol production. In section 4.2.1 this data provided shadow priced and in section 4.2.2 a monetary value is put on the reduction of CO_2 that the investment results in. In section 4.2.3 this is then put together and a social NPV is estimated.

4.2.1 Estimation of shadow prices to be used to get a social NPV

Here the operation cost from table 4.2 has been valued to their opportunity costs and distorting effects have been taken away. The grey area in table 4.4 highlights the modifications that have been done. The net cash flow presented here is about 24,000 millions SEK lower than the figure introduced in table 4.2 above. The assumptions taken are discussed and explained below.

Shadow pricing of SvL's financial calculations			
Fixed investments			
Machinery			1,117,218,789
Buildings			302,781,211
Total investment			**1,420,000,000**
-			
Operation Costs	**Units**	**SEK/unit**	**Total cost**
Labour (36 employees *40h/week*46 week/year)	66,240	173	11,438,721
Electricity KWh (fermentation & distillation)	39,583,601	0.617	24,423,082
Electricity (animal feed)	35,600,000	0.617	21,965,200
Labour cost transportation (feed and bioethanol)	154,323	104	15,989,653
Cost for diesel for transportation	914,000	5.6	5,132,110
Total operation costs			**905,167,568**
-			-
Revenues	**Units**	**SEK/unit**	**Total revenues**
Bioethanol 220 000 m3	220,000,000	5.5	1,210,000,000
Feed	180,000,000	1	180,000,000
Total revenues			**1,390,000,000**
Net cash flow (revenues-costs)			**484,832,432**

Table 4.4 The shadow pricing of SvL financial calculations that is to be used in the social CBA

To get the opportunity cost for labour there are a few variables to consider. The employment tax is, as discussed in section 2.3.1, a distortionary tax and should therefore be taken way. This tax is 32.28% and it is based on the gross salary (Swedish tax agency, 2006). In the same section it was argued that the income tax should be left in and therefore this is not adjusted for here. In Sweden the unemployment rate is rather high. In June 2006 8.2% of the population in-between 16-64 years were unemployed. (SCB, 2006) There are a wide range of government programmes which purpose is to improve the statistics. It is often argued that this figure in reality is in-between 15-20% when the hidden unemployment has been accounted for as well. (DN 2006) It will therefore here be assumed that 15% of the labour will not be able to get a job under the period for the investment in the bioethanol factory. The opportunity cost for labour working in the factory used here is therefore 173 SEK/h (300-32.28%*0.85) and 104SEK/h lorry drivers (180-32.28%*0.85). These adjusted costs are presented in table 4.4.

Also the cost for energy is shadow priced. The tax on diesel is 3.66 SEK per litre; of which 1.04 is a fiscal energy tax and the rest 2.62 per litre is carbon tax. (SPI, 2006a) When the tax is subtracted from the market price, 9.28, the shadow price is 5.62 SEK/litre diesel used for transportation. Even thought, according to the classification provided in section 2.3., one part of the tax is pigouvian and the other is a distortionary tax both are here taken away. The reason for this is that this is already adjusted for by the values calculated in 4.2.2. Without adjustment of this it would be a double counting. The tax rate for electricity used in manufacturing industry and agriculture the tax is 0.005 SEK per kWh. (Swedish tax agency, 2006) Here the same discussion is held. When this tax is taken away the shadow price is 0.617 SEK/KWh.

4.2.2 The value of CO_2 emissions to be used to get a social NPV

In this section the net reduction of CO_2 emissions that are saved through consumption of bioethanol as substitute to petrol is valued in monetary terms. Three values from figure 2.7, a small, middle and a large, have been chosen to represent the SCC in these calculations. Different costs for CO_2 emissions are used in order to understand how the level of the SCC affects the social NPV.

As shown in table 4.1 the CO_2 emissions that are emitted during the production of 220 000 m^3 bioethanol are under the assumptions taken in this research about 16 600 tonnes. When this produced bioethanol is used as a substitute to petrol as fuel for transport this means, as discussed in 4.1.2.3, that the 340 000 tonnes CO_2 emissions that would have been released if petrol was used is not emitted to the environment. This signifies that the production of bioethanol at SvL's factory thereby gives a net reduction of 323, 000 tonnes. The production of animal feed is as discussed in 4.1.1 an energy intensive process that uses about 50% of the electricity and steam. Since this part of the production process consumes so much energy it is often argued that there should be an allocation when analysing environmental benefits so that the animal feed carries its own emissions. In studies that analysis the environmental benefits of bioethanol this is often used and referred to as physical allocation. (Bernesson, 2004, Börjesson, 2006) This is reason why the energy for bioethanol and animal feed is separated in table 4.2.However, in order to make the calculations as correct as possible in this research it is argued that animal feed would not have been produced if there where no bioethanol production and therefore no physical allocation is used.

In table 4.5 this net reduction is value in monetary terms according to the values given by Pearce, AIE & SEI and the FUND 2.8. (See A10 for details of the calculation). It is shown that the net benefit involved with reduction of CO_2 emissions increases when the SCC increases.

Valuation of the net reduction of CO_2 emissions		
322,644 tonnes	*SEK/ton*	*Total SEK*
PEARCE	14	4,471,842
AIE, SEI	132	42,716,835
FUND	238	76,890,303

Table 4.5 The value of the net reduction of CO_2 emission

4.2.3 CBA of the production of bioethanol at SvL

Here the private NPV calculated in table 4.3 is recalculated with a net cash flow that has been adjusted by the figures provided in section 4.2.1 and 4.2.2. The net benefit form CO_2 reduction has then been added to the adjusted net cash flow from table 4.4. After these adjustments the social net cash flow is higher than the private NPV that was calculated for SvL's investment in bioethanol production above (See appendix A11 for the more detailed spread sheet). The social NPV given from this is illustrated in table 4.6 below. It is found that the social NPV is considerable higher than the private NPV presented in table 4.3. With FUND values the investment gives an IRR of 65% (to be compared with 32% from table 4.3). Then comparing this with AIE &SEI and Pearce it is however shown that the IRR is slightly better when the cost for emitting carbon emissions increases.

The social NPV and IRR for SvL's production of bioethanol (million SEK)

Fund				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	6,469	4,972	3,414	2,426
IRR	**65%**			
AIE, SEI				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	5,989	4,583	3,120	2,192
IRR	**59%**			
Pearce				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	5,448	4,145	2,789	1,929
IRR	**52%**			

Table 4.6 The social NPV of SvL's production of bioethanol (million SEK)

As discussed in 4.1.2.4 the IRR would be considerable affected if the cost for energy or the price for cereals would rise by 20% or if the price of bioethanol would decrease by 20%. As shown in appendix A12 it would be a relatively large drop also of the social NPV, about 7% for increases in energy prices, over 30% with an increase in the price of cereals and a drop around 60% if the price of bioethanol would decrease.

4.2.4 Discussion off the findings in section 4.1 and 4.2

These two sections have been presented in order to approximate a value of the social net benefits associated with the bioethanol production from cereals in Sweden. As shown in section 4.2.3 the aggregated social NPV from production of bioethanol at SvL's factory in Sweden is about 6.469 million SEK with FUND when using the 1.8% discount rate. This figure is about 1000 million lower if the Pearce estimation about SCC is used. When the highest discount rate, 15%, is used however these values are only slightly more than a third of these figures. These figures are higher than the figures in the financial appraisal in table 4.3 and that indicates that there is a value for the reference and the non-reference group involved in the investment. How this is distributed within the Swedish society is studied further in section 4.3. When evaluating these results it is also important to consider the likelihood of large fluctuations in the prices of inputs and outputs. As discussed in 4.1.2.4 (further shown in A7) the results are rather sensitive to changes in the prices of cereals and energy and drops in the price of bioethanol.

Since there is a customs on imported bioethanol in the EU it can be argued that the world market price for bioethanol should be used instead of the domestic price paid for bioethanol in Sweden. In this CBA Sweden is looked at and evaluated as a separated area and it is therefore reasonable to use 5.50 SEK/ litre in the calculations. It must however be stressed that the customs put on biofuel is heavily criticised and can therefore very well be reduced or taken away in the future. If the customs were taken away the prices on bioethanol would be lowered in the EU. As discussed above the result is rather sensitive to decreases of the price paid for the bioethanol. Assuming that it would result in a reduction of the price of 1.80 SEK/ litre (which is the level of the custom) the result in table 4.2 would be lowered by 396 million SEK which would then render the project rather marginal. It could for example be observed that the net present value of the project in terms of SvL becomes negative at a 5 % discount rate and amounts to - 744 million SEK which corresponds to an annual loss of 0.096 x 744 = 71.4 Million SEK (compare Table 4.3).

It should also be noted that the social NPV is substantially reduced. It could for example be observed that the social net present value of the project at a 1.8 and 5 % discount rate is reduced to +283 and +35 Million SEK respectively in the Pearce scenario (Table 4.6). Clearly, international trade and custom regulations play a very decisive role when the economic viability of bioethanol production is examined.

So what discount rate should be used? As discussed in 2.3.3 a market based discount rate adjusted for inflation, adapted from a security with the same or similar duration is often used to determine long term social projects. In this research this rate is estimated to 1.8%. It is arguable whether the lower interest rate actually is used or if projects in reality are evaluated according to a more competitive interest rate. If an investment is evaluated from a company's perspective the discount rate used is naturally higher. However, the lower the discount rate is the more defendable it is from the society's viewpoint to support the domestic production of bioethanol through tax exemption. It should be stressed that the interest rate used here is adjusted for inflation and therefore 10% and 15% must be considered as a rather extreme sensitivity analysis. Most focus should therefore be on the values calculated for the 1.8% and the 5% interest rates in this study.

It is shown that under the assumptions taken in this research there is a large net reduction of CO_2 emissions. In comparison to the without the project scenario where there were no usage of bioethanol, there is a saving of about 323 000 tonnes. So which of SCC is most relevant to use to put a value on this? This is arguable and with no doubt very difficult to be sure about since there is no consensus among scientists. As observed in 2.5 the values also changes largely with different discount rates and equity weighting used. However, it is probably reasonable to think that the SCC in reality is relatively high since there is a large uncertainty and difficulty to measure the benefits and costs regarding climate change. Since the FUND model, as discussed in 2.5.1.1 are used as point of reference for EU and that the majority of the SCC values presented in figure 2.7 are higher than both the values presented by AIE &SEI and Pearce it could be argued that the value presented by FUND is closer to the reality than the other values. This is however something that only that future will tell us. Other environmental problems involved with the investment have however, as discussed in the research strategy in 3.1, fallen outside the limit of this study.

As discussed in 2.1.2 the EU is aiming for reduced oil dependency and the biofuels directive is one step in the right direction. This is something that should be considered when evaluating the investment in renewable technology. However, it is difficult to estimate the value for this per unit and this is therefore not evaluated in monetary terms and used in the CBA. The result under the undertaken assumptions is that about 136 500 m^3 petrol equivalents annually is "saved" compared with the without scenario. (This value is given by diving the net saving of CO_2 emissions by 2.36 ton CO_2/ m^3 and subtract this from the 144 000 m^3 petrol equiv. that the bioethanol produced is substituting) This is however a rough estimate but it is an indicative result. SvL's production of bioethanol results in an actual reduction of fossil fuels dependency.

4.3 Distributional effects

As discussed in section 2.4 it is often, in order to understand whether to invest in a project or not, important to evaluate the distributional effects and understand how large benefits/costs that distribute to separate groups. In this section the distribution effect within Sweden is therefore evaluated. This is done in order to identify winners and losers in the Swedish society in bioethanol production and quantify the effects for them.

4.3.1 How is the distribution within the reference group

When calculating the social NPV for the production of bioethanol in section 4.2.3 this value includes the reference group as well as the company and the non-reference group. To get the distributional effects from SvL's investment in bioethanol the reference group is therefore separated from the other two in this section. To do this it is therefore necessary to identify groups within the society that experience cost or benefits due to this project and have a Swedish location. Since the reference group is Sweden foreign groups are, as discussed in section 2.4, part of the non-reference group and should therefore not be considered in this analysis. For each group that is part of the reference group a net cash flow should be approximated in order to get an individual NPV. As discussed in section 2.4 such information is found in the shadow prices and the in financial flows. In appendix A13 the spreadsheet used for this is introduced and the origins of the figures are further explained. Table 4.7 presents the distributional effect for each group individually.

Distributional effects within groups within the Swedish society (million SEK)

Groups	1,80%	5%	10%	15%
Government	-3 854	-3 072	-2 258	-1 740
Labour factory	26	21	15	12
Labour transport	37	29	22	17
Maintanence suppliers	1 111	884	648	498
Bank	456	384	304	248
Insurance company	289	230	168	129
Chemical companies	366	291	213	164
Water company	47	38	28	21
Environment	1 003	798	585	450
Total ref. group FUND	**-519**	**-397**	**-275**	**-201**
….				
Environment(AIE, SEI)	557	443	325	250
Total ref. group	**-964**	**-752**	**-535**	**-401**
….				
Environment (Pearce)	58	46	34	26
Total ref. group	**-1 463**	**-1 149**	**-826**	**-624**

Table 4.7 Distributional effects for different groups within the Swedish society

For the government the tax received through employment and fuel is considered. The reduced income due to the tax exemption on biofuels is also taken into account in this section and this explains the negative effect for the government in table 4.7. Only the energy tax is considered as a tax loss here, 2.86 SEK/litre petrol equivalents (Swedish tax agency, 2006). The government's loss of carbon tax revenue will however not be considered in the analysis of the distributional effects since it is a loss due improved environmental performance of bioethanol compared to fossil fuels. It would therefore be unfair to account bioethanol for the revenue loss since it is one of the government's major policy goals. The value of increased employment in the factory and the transport sector adapted from the shadow prices, discussed in 4.2.1, is also presented here.

There is a knowledge gap in this research about the origin of some of the groups considered. It could therefore possibly be argued that some of the groups, fully or partly, are not owned by Swedish citizens. In this research however the bank, the insurance company water company, the maintenance- and chemical supplier are all assumed to be Swedish. They are then a part of the reference group and are thereby also listed in table 4.7, financial flows adapted from table 4.2. The oil company and the energy supplier are however assumed not to be Swedish. This means that they fall outside the reference group and should therefore not be accounted for when the distributional effect of the project is investigated. The benefit for farmers as well as a monetary value for increased open landscape is not considered here since it is assumed in this study that the farmers would produce cereals even without the existence of the bioethanol factory.

4.3.2 Discussion of the findings in section 4.3

In section 4.3 the distributional effect that SvL's investment in bioethanol production causes within the reference group is analysed. There are a number of groups within Sweden that are assumed to benefit from SvL's investment according to these calculations. The environment, the bank, the chemical companies and the maintenance suppliers are all relatively large gainers. The value for the environment is largely dependent of how high the avoidance of CO_2 emissions emitted to the atmosphere is valued and clearly also how much CO_2 that actually is reduced. When it is valued according Pearce (14 SEK/t CO_2) the monetary benefit to environment is not very large whereas if the much higher value proposed by the FUND is used (238 SEK /t CO_2) the environment is profiting a lot by the investment. As presented in table 4.7 the government is loosing out due to SvL's investment in bioethanol production. The company tax and the tax exemption for biofuels are examples of taxes that should not be accounted for in the social NPV since they are transfer taxes. However when evaluating the distributional effects such capital flows should be included in the analysis. This is the reason why the aggregated total reference group NPV added with the private NPV not equals the value for social NPV in section 4.2.3The NPV for the total reference group differs with the different values put on the SCC. With 1.8% discount rate the net reduction of the CO_2 emissions the NPV is about -518 million SEK with "FUND" whereas it is -1 463 million SEK with "Pearce". It is interesting to see, as discussed in 2.3.3, how the value of an investment reduces with an increasing discount rate. As shown in table 4.7 the net environmental benefits has a much lower NPV if a high discount rate is used then if a low rate is applied. This indicates that the importance of investments in environmentally friendly technologies reduces with rising discount rates.

4.4How would the results change with a different "without the project" scenario?'

Until now there has been assumed that the wheat used in the bioethanol factory would have been produced even if there where no factory. The production of wheat is however rather energy demanding and much CO_2 emissions are emitted during this phase. During the cultivation and transport of the 590 000 tonnes wheat that is assumed to be used for the bioethanol production at SvL's factory 225 000 tonnes CO_2 equiv. emissions are estimated to be released. The total energy input during the cultivation and transportation is 1 370 000 GJ. This cultivation process gives however also rise to 830 000 working hours annually. (The assumptions made to calculate this are all presented in appendix A14) These figures are considerable in comparison to the figures regarding energy requirement and the level of CO_2 emissions discussed above. It is therefore reasonable to discuss how the results of this research would change with modified assumptions taken.

If it is assumed that all the agricultural land that is used to produce wheat for SvL's factory would not be cultivated at all in the without the project scenario the result would be different from the result presented in this study. In that case the CO_2 reduction due to the investment would be about 98 000 tonnes instead of the 323 000 tonnes. (See appendix A14) This would signify that the reduction of oil dependency would not be as large as discussed in 4.2.4. If the same calculation method is used the project would "save" only about 42 000 m^3 petrol equivalents compared to the 136 500 m^3 (this is however a rough estimate and is indicative) that was argued above. This is due to the extensive tractor usage, that oil is used for drying of the cereals for the production and transportation of fertilizer and chemical etc. This result in a lower social NPV than the result presented in table 4.6 above

These assumptions would however result in employment for farmers and rural development. Cultivation would also result in open landscapes for the country side. It is however rather difficult to identify a value of how much people are prepared to pay to keep open landscape. One study by Drake (1991) is using contingent valuation to estimate how much people in Sweden are prepared to pay to preserve the agriculture landscape. He comes to the conclusion that people's willingness to pay is 860 SEK/ha (1991prices) for land with cereal production. This value does however, as argued by Drake, have a low degree of precision and does vary with the location and is correlated to level of income, age and education. (Drake, 1992, Drake, 1999) The value of open landscapes naturally also stands in conflict with other interests in the society such as infrastructure changes and environmental protection etc. With this latter scenario it should also be remembered that cultivation of wheat also is a source for eutrophication and discharges of pesticides even though it has been ignored in this research. This might have a large negative value.

4.5 General discussion

The social CBA in this research shows that there can be a relatively high net benefits involved with the bioethanol production in Sweden. It is however found that the social NPV is sensitive to changes in prices of inputs and outputs. If there is an increase of energy and cereal prices or a decrease of the price of bioethanol the social net benefits of bioethanol production decreases. It should therefore be remembered that the wheat market for human food consumption mirrors the market for the wheat for bioethanol production. This indicates also that the attractiveness for investment in bioethanol production should rise with increased prices on fossil fuels.

So is it then a good idea for the government to support the development if bioethanol from cereal production with total tax exemption? As mentioned above this research indicates that the bioethanol production provide positive social NPV and groups within the Swedish society benefit from the investment. It is however shown that it is very costly for the government and it must therefore be discussed whether this is the best usage of tax money. In order to evaluate whether such support is cost effective the total environmental effects should be evaluated. It is important to be aware of this in order to prevent technological lock-ins in inefficient production systems for bioethanol or any other system for renewable fuel. Due to the energy losses during the production process the "saving" of fossil fuels should be sizeable to defend production of bioethanol instead of using fossil fuel directly. It is important to point out that if fossil fuels are used instead of biomass to produce the steam and electricity for the factory (which is the case in many countries in Europe) much more CO_2 emission would be emitted during the production process than the values suggested in this study. If countries are relying on fossil fuels for its energy and electricity production it might therefore be of higher priority to first to improve these areas, before biofuels production is introduced into the transport sector. The research in this thesis shows that there are relatively good environmental benefits. If other assumptions would have been made and the whole production process would have been considered the bioethanol would look less favourable. It is however deemed to be unfair to make a fall inclusion since it is very unlikely that land use would change without the project. It is also essential to consider the level of SCC chosenit is important for the reader to realise the impreciseness of this value and its consequents in the future. It must further be questioned whether bioethanol and this type of production method is the future solution for the energy requirement in the transport sector or if it fits in a mix of different production methods.

Even thought it might be reasonable to think that bioethanol from cereals on its own not will be able to substitute petrol in the transport sector it can be argued that it is a starting point to the development of renewable fuels in the transport sector. It can be seen as an injection to the market that pushes it forward and makes people aware of more environmentally friendly and domestically produced transport fuels.

4.6 Chapter findings

The most important findings from chapter 4 are presented below.

- There is a social net benefit involved with the investment in bioethanol. (See the table below) This net value is however dependent on the discount rate chosen and to what level the CO_2 emissions are valued. The values calculated for 1.8% and 5% are considered the most reasonable value to use.
- According to the assumptions taken in this research 323 000 tonnes CO_2 is "saved" by the investment in bioethanol production. The level of reduction of emissions and the value put on SCC has large importance for the profitability of investments in environmentally friendly technology.
- The result of this research is sensitive to changes in the price of energy, cereals and the price paid for bioethanol. Therefore the likelihood of large fluctuations of these variables has to be considered when evaluating investment in bioethanol production from cereals.

The social NPV and IRR for SvL's production of bioethanol (million SEK)

Fund				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	6,469	4,972	3,414	2,426
IRR	**65%**			
AIE, SEI				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	5,989	4,583	3,120	2,192
IRR	**59%**			
Pearce				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	5,448	4,145	2,789	1,929
IRR	**52%**			

- There are groups within the Swedish society that benefits from the bioethanol production (See the table below) The government is however the looser of the investment due to the reduced tax income due to the total tax exemption of bioethanol.
- The values are adapted from the financial flows and from the adjustments in shadow prices. It is only members of the reference group, the Swedish society that should be included in this analysis. The firm and groups that is not owned by Swedish citizens should be excluded.
- The value of environmental benefits reduces with increased discount rates. This indicates that with high discount rate investments in environmentally friendly technologies has less importance.

Distributional effects within groups within the Swedish society (million SEK)

Groups	**1,80%**	**5%**	**10%**	**15%**
Government	-3 854	-3 072	-2 258	-1 740
Labour factory	26	21	15	12
Labour transport	37	29	22	17
Maintanence suppliers	1 111	884	648	498
Bank	456	384	304	248
Insurance company	289	230	168	129
Chemical companies	366	291	213	164
Water company	47	38	28	21
Environment	1 003	798	585	450
Total ref. group FUND	**-519**	**-397**	**-275**	**-201**
....				
Environment(AIE, SEI)	557	443	325	250
Total ref. group	**-964**	**-752**	**-535**	**-401**
....				
Environment (Pearce)	58	46	34	26
Total ref. group	**-1 463**	**-1 149**	**-826**	**-624**

Changes in the assumptions taken in the research can however modify the results. If it for example would be assumed that there would be no cultivation of the agricultural land without the bioethanol factory the result of the research would be different. In such a scenario the difference between the “with” and “without” the investment scenario would be larger than discussed above. The CO_2 emissions and the energy requirement for the cultivation of wheat are fairly high due to high tractor usage, drying of the cereals and fertilizer and chemical production. This would therefore reduce the CO_2 “saving” and would also modify the value for the fossil fuels used during the production process. This would reduce the calculated social net benefit. On the other hand there would other variables to consider such as employment in rural areas and contribution to an open landscape.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This result in this study indicates that bioethanol production from cereals in Sweden can give rise to social net benefits in form of reduced CO_2 emissions and creation of economic activity within the country. After assumptions taken in this research the calculated social NPV from production of bioethanol at SvL's factory in Sweden is estimated to be about 6.469 million SEK with the carbon evaluation FUND (238 SEK/t CO_2) when using the 1.8% discount rate. This figure is about 1000 million lower when Pearce's carbon value estimation is used (14 SEK/ t CO_2). These values can however vary with fluctuations in the prices of energy, cereals and the price paid for the finished product and therefore the likelihood of such changes should be kept in mind when evaluating the values calculated in the CBA.

It is here argued that it is reasonable to put a high value on the SCC due to the insecurities regarding climate change. It is also argued that the importance of investments in environmentally friendly technologies decreases when a high discount rate is used. Before decisions are made to support environmentally friendly technology it is under all circumstances important to make careful studies in order to understand the real net benefits and the actual reduction of CO_2 and oil consumption involved with the production. This is important in order to prevent technological lock-in in inefficient technology that does not fulfil the overall policy of reduction and reduced oil dependency.

The net benefits are distributed both within and outside the Swedish society. The government is the "group" within the society that is loosing when the distributional effect is analysed. This is however natural since CO_2 reduction is part of the government's overall policy and this would be difficult without an initial push from their side. It should however be evaluated whether there are better and more cost more effective technologies to support. It is important to consider also other technologies so that Sweden does not look themselves into technologies that do not reach the goals that have been set for reduction of greenhouse gases.

5.2 Suggestion for future research

In order to make this study feasible this research is based on a range of averages, assumptions and simplifications (discussed throughout the study). The values regarding the social NPV and the distributional effects are therefore naturally not the correct value but indicative figures and an attempt to make estimation in this area. There are also areas that have not been possible to include due to constraints in time and information. In future research it would therefore be interesting to also include other parameters in monetary terms in the CBA, for example the value of reduced oil dependency and open landscapes. It would also be valuable to be able to extend the research to also include other environmental concerns such as acidification, eutrophication and impacts on the air quality.

CHAPTER 7

REFERENCES

7.1 Written sources

AEA (AEA Technology Environment), (2005)*The Social Cost of Carbon(SCC)Review-Methodological Approaches for Using SCC Estimates in Policy Assessment-Final report December 2005*, DEFRA, UK, http://www.defra.gov.uk/environment/climatechange/carboncost/pdf/aeat-scc-report.pdf

Albert, S., Hopes, C., (2006) *Developing the PAGE2003 Model with Endogenous Technical Change*, University of Cambridge http://www.electricitypolicy.org.uk/pubs/wp/eprg0613.pdf

Bernesson, S., (2004) *Life Cycle assessment of rapeseed oil, rape methyl ester and ethanol as fuels*, Miljö, teknik och Lantbruk Rapport 2004:01, Swedish University of Agricultural Sciences, Department of Biometry and Engineering ISSN 1652 3237, Uppsala, Sweden

Brent, R., (1997), *Applied Cost-benefit analysis*, Edgwar Elgar publishing Limited, ISBN 1-85898-285-5

Brown, R., Campbell, H (2003). *Benefit-Cost Analysis- financial and economic appraisal using spreadsheets,* Cambridge University Press, ISBN 13- 978-0 521-52898-6

Borjesson, P., (2006), *Energibalans for bioethanol-en kunskapsoversikt (Energy balance in bioethanol, a survey)*, Rapport 59, University of Lund, Sweden, ISBN 91-88360-82-2

Clarkson, R., Deyes, K., (2002), *Estimating the social cost of carbon emissions*, DEFRA**,** Government Economic Service Working Paper 140 http://www.hm-treasury.gov.uk/mediastore/otherfiles/SCC.pdf

DEFRA, (2006), *Climate Change -The UK Programme 2006,* CM6764 SE/2006/43, Visited 2006-06-20 http://www.defra.gov.uk/ENVIRONMENT/climatechange/uk/ukccp/pdf/ukccp06-all.pdf

Drake, L, (1999), *The Swedish agricultural landscape-economic characteristics, valuations and policy options*, International Journal of Social Economics volume 26, pp. 1042-1060, Uppsala, Sweden

Drake, L, (1992), *The non-market value of the Swedish agricultural landscape*, Euro. R. Agr. Eco 19, pp. 351-364, Uppsala, Sweden

Daffern, P., & Walshe, G., (1990), *Managing cost benefit analysis*, Macmillan, ISBN 0333480384

European Commission (EC), (2006a), *Biofuels in the European Union A VISION FOR 2030 AND BEYOND -Final draft report of the Biofuels Research Advisory Council,* Visited 010606*,* http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf

European Commission (EC), (2004a) *Biofuels Barometer June 2004*, EurObserver, Visited 020606, http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro167b.pdf

European Commission (EC), (2005) *Biofuels Barometer June 2005*, EurObserver *http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro161.pdf*

European Commission' homepage (EC), (2006b), Visited 06202006, http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/02/120&format=HTML&aged=0&language=EN&guiLanguage=en

European Commission (EC), (2003) *Directive 2003/03/30/EC of the European Parliament and of the council,* Official Journal of the European Union, ISBN 92-894-7457-2, http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf

European Commission (EC), (2004b), *Energy and Transport, report 2000-2004***,** http://ec.europa.eu/dgs/energy_transport/figures/report_2000_2004/doc/dg_tren_bilan_2000_2004_en.pdf

Guo, J., Hepburn, C., Tol, R., Anhoff, D., (2006), *Discounting and the social cost of carbon: A closer look*, Environmental Science & Policy 9, pp 205-216,

International Energy Agency (IEA), (2005), *Key World Energy Statistics 2005*, http://www.iea.org/dbtw-wpd/Textbase/nppdf/free/2005/key2005.pdf

International Energy Agency (IEA), (2004) *Biofuels for transport: an international perspective*, http://www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf

Hunt, A., Markandya, A., (2004), *ExternE-Pol Externalities of Energy: Extension of Accounting Framework and Policy Applications*, Final Report on Work Package 3 -The externalities of Energy Security, Bath, UK

NewExt (2004)*, New Elements for Assessment of External Costs from Energy Technologies- Publishable Report to the European Commission*, Germany, http://www.ier.uni-stuttgart.de/forschung/projektwebsites/ newext/newext_final.pdf

Norrkoping Water, (2005), *Prisblad 2005 Vatten och avlopp*, http://www.norrkoping.se /miljo-natur/vatten/ pdf/prisbladovrigt.pdf#search=%22Prisblad%202005%20Vatten %20och%20avlopp%20och%20norrk%C3%B6pings%20vatten%22

Perman, R and Ma, Y and McGilvray, J and Common, M , (2002), *Natural Resource and Environmental Economics (3rd ed.)*. Harlow, England. Person Education Limited.

Robson, C, (2002), *Real World Research (2nd ed.)*, Oxford UK, Black Publishing, ISBN 0631213058

King, D., (2005), *Thirteenth bes lecture; Climate change: the science and the policy*, Journal of Applied Ecology 42. 779-783, London

Krewitt, W., (2002), *External cost of energy-do the answers match the questions? Looking back at 10 years of ExternE*, Energy Policy 30, pp. 839-848

Statistics Sweden, **(SCB)** (2006), *Sveriges ekonomi ur ett statistiskt perspektiv*, (Swedish economy from a statistic perspective), Number 2 2006, http://www.scb.se/statistik/_publikationer /AA9999_2006K01_TI_A28ST0602.pdf

Statistics Sweden, **(SCB)** (2002*), Medellön i de tio vanligaste yrkesgrupperna 2002 (The average salary in the ten most common occupations 2002)* , **http://www.scb.se/templates/tableOrChart____27555.asp**

SEI, **(Stockholm Environmental Institute),** (2005) *Social cost of carbon: A closer look at uncertainty, Final Project report November 2005*, Oxford Office, http://www.defra.gov.uk/environment/climatechange/carboncost/pdf/sei-scc-report.pdf

Swedish Agriculture Agency (SAA) Jordbruksverket, (2004)*, Marknadsöversik-Etanol, en jordbruks- och industriprodukt-Rapport 2004:21 (An overview over the ethanol market-Ethanol an industry- and agricultural product),* Jordbruksverket, Visited 010606*,* http://www.sjv.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra04_21.pdf

Swedish Energy Authority (SEA) Statens Energimyndighet**,** (2005) Energiläget *2005*, http://www.stem.se/web/biblshop.nsf/FilAtkomst/ET2005_23w.pdf/$FILE/ET2005_23w.pdf?OpenElement

Swedish Environmental Protection Agency's (Swedish EPA) homepage, (2006), Visited 06-20-2006 http://www.internat.naturvardsverket.se/index.php3?main=/ documents/issues/climate /climate.htm

Swedish Environmental Protection Agency's (Swedish EPA), (2005) *Miljövärdering, samhällsekonomiska konsekvensanalyser och ekonomiska modeller för hållbar utveckling – en forskningsöversikt,* http://www.naturvardsverket.se /dokument omverket/forskn/ aktuell/utlys/kristr.pdf

Swedish Environmental Protection Agency's (Swedish EPA), (2004) *Skattebefrielse pa etanol.leder den ratt?(Tax exemption on bioethanol, is that the right way to go?,* Rapport 5433, Stockholm, ISBN 91-620-5433-3-pdf

Swedish Government, (2004) *Introduktion av förnybara fordonsbränslen SOU 2004:133 (Introduction of renewable fuels for the transport sector),* http://www.sweden.gov.se/content/1/c6/03/67/01/bb423867.pdf

Swedish Government (2007), http://www.ud.se/sb/d/8709/a/77187

Swedish Government (2003), *Skatt på handelsgödsel och bekämpningsmedel?-SOU 2003:9, Stockholm*, **Swedish National Dept Office's homepage**, (2006), Visited 20-07-2006, http://www.rgk.se/

Swedish Tax Agency, (2006), *Excise duties- SKV 510 Edition 10*, Sweden, http://www.skatteverket.se/download/18.3a2a542410ab40a421c8000400/51010.pdf

The Swedish Petroleum Institute (SPI), (2006a), *Skatteoversikt-skattesatser enligt Lagen om skatt pa energi* (SFS 1994:1776), http://www.spi.se/fprw/files/Skatteöversikt%202006%20ver%202.xls

The Swedish Petroleum Institute (SPI), (2006b), *Energiinnehåll, densitet och koldioxidemission* (Energy content, density and CO_2 emissions) http://www.spi.se/omraknfakt.asp

Tol, R., (2005), *The marginal damage cost of carbon dioxide emissions: an assessment of the uncertainties,* Energy policy 33 pp. 2064-2074, http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/enpolmargcost.pdf

United Nations Framework Convention of Climate Change's homepage (UNFCCC), (2006), Visited 06202006, http://unfccc.int/essential background/ kyotoprotocol/ items/ 2830.php

Weitzman, M., (1998), *Why the far distant future should be discounted at its lowest possible rate*, Department of Economics, Harvard University, Cambridge, Massachusetts, Journal of Environmental Economics and Management 36 Article no. EE981052, pp. 201-208

Personal Communication

Beckaman, B.,(2006), *Personal Communication during site visit at SvL,* Purchasing Manager ,Lantmännen Agroetanol, Interviewed 052306 http://www.agroetanol.se/ http://www.agroetanol.se/

Werling, K., (2006) Managing Director, *Personal Communication during site visit at SvL* Lantmännen Agroetanol, Interviewed 052306

Kindegard, L., (2006) Informant, Norrkoping's Water, Telephone communication, nb. 0046-11-153693, Norrkoping , Sweden

APPENDICES

A1 The sectors used to calculate the SCC in the FUND

Sector	Description
Agriculture	Impacts are positive or negative depending upon whether regional T is moving closer or further away from the climate optimum (influenced by plant physiology and farmer behaviour) with adaptation explicitly modelled
Cooling	Energy costs due to cooling—i.e. air conditioning
Death	People can die prematurely due to temperature stress (cardiovascular and respiratory disorders related to heat and cold stress) or due to vector-borne diseases (malaria, dengue fever, schistosomiasis, diarrhoea); VSL (value of a statistical life) set to be 200 times the annual per capita income in the region
Dryland	Losses of dryland due to sea level rise without defences; value assumed to be proportional to GDP per square km
Emigration	Losses experienced by individuals displaced by sea level rise; set to three times per capita income
Forests	Damages and benefits incurred by the forestry sector due to rising temperatures
Heating	Energy heating costs incurred or saved by T variation
Immigration	Costs of settling immigrants displaced by sea level rise; immigrants are assumed to assimilate after a short time and to no longer 'cost' the host government; costs set to 40% of per capita income in the host country
Morbidity	Damages due to individuals with ill health from heat related stress (cardiovascular or respiratory disease) or vector-borne diseases (malaria, dengue fever, schistosomiasis, diarrhoea)
Sea rise protection	Response costs incurred in building sea rise defences; the decision to protect wetlands and dryland from sea level rise is made annually; increasing amounts are protected as the economy grows
Species	Impacts on species (unmanaged ecosystems) are modelled as a simple power function and are assumed to be negative with increasing temperatures; value is determined relative to per capita income on a 'warm glow' basis (i.e. that actual amounts lost are irrelevant, but the fact that something is lost is relevant—thus this is a measure of the non-use value of biodiversity to individuals and not an attempt to value any loss of ecosystem services)
Water	Impacts on water resources (with changing availability and demand) are modelled as a simple power function and are assumed to be negative with increasing temperatures
Wetlands	Losses of wetlands due to sea level rise where no defences built; value assumed to have a logistic relationship to per capita income

Acronym	Name	Countries
ANZ	Australia and New Zealand	Australia, New Zealand
CAM	Central America	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
CAN	Canada	Canada
CEE	Central and Eastern Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, FRY Macedonia, Poland, Romania, Slovakia, Slovenia, Yugoslavia
CHI	China plus	China, Hong Kong, North Korea, Macau, Mongolia
FSU	Former Soviet Union	Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
JPK	Japan and South Korea	Japan, South Korea
MDE	Middle East	Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank and Gaza, Yemen
NAF	North Africa	Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara
SAM	South America	Argentina, Bolivia, Brazil, Chile, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
SAS	South Asia	Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka
SEA	Southeast Asia	Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand, Vietnam
SIS	Small Island States	Antigua and Barbuda, Aruba, Bahamas, Barbados, Bermuda, Comoros, Cuba, Dominica, Dominican Republic, Fiji, French Polynesia, Grenada, Guadeloupe, Haiti, Jamaica, Kiribati, Maldives, Marshall Islands, Martinique, Mauritius, Micronesia, Nauru, Netherlands Antilles, New Caledonia, Palau, Puerto Rico, Reunion, Samoa, Sao Tome and Principe, Seychelles, Solomon Islands, St Kitts and Nevis, St Lucia, St Vincent and Grenadines, Tonga, Trinidad and Tobago, Tuvalu, Vanuatu, Virgin Islands
SSA	Sub-Sarahan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo-Brazzaville, Congo-Kinshasa, Cote d'Ivoire, Djibouti, Equatorial guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
USA	USA	United States of America
WEU	Western Europe	Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom

(Source: DEFRA, 2006)

This table explains the areas that are taken into account and how the world is divided geographically when estimating the SCC in the FUND 2.8.

A2 The spreadsheet- the key variables upon which the calculations are based.

The spreadsheet is constructed to calculate the social CBA of SvL's investment in bioethanol production and there are five main spreadsheets. The sheet that is shown below provides the key variables upon which all calculations are based. The sheet called Project CBA (presented in A6, named) and the Private CBA (presented in A7) are both used to evaluate the investment from SvL's perspective. Information given during these calculations is then used for calculations under the sheet social CBA (presented in A11) and the reference group CBA (presented in A13)

A3 Detailed information about energy and CO_2 emissions for different inputs

In this section more detailed information about the figures and assumptions used when estimating the total energy requirement and the total CO_2 emissions emitted during the production of bioethanol are presented. When calculating CO_2 equivalents CO_2 equals 1, CH_4 equals 23 and N_2O equals 296 CO_2 equivalents.(Bernesson, 2004)

A3.1 Chemicals used in the bioethanol factory

A3.1.1 The chemicals and the amount per tonne wheat

Here the amount of chemicals (kg) and the price per kg for these chemicals that is assumed to be used in the bioethanol factory per tonne wheat is presented. (Source: Bernesson, 2004)

Chemical	Amount [kg/tonne wheat]	Pure [kg/tonne wheat]
Phosphoric acid (75%)	0.160	0.120
Sulphuric acid (93%)	2.152	2.001
Sodium hydroxide (50%)	0.310	0.155
Calcium chloride (30%)	1.366	0.410
Other chemicals	0.177	0.177
Scum reduction agent	0.055	0.055
Novo BAN 240 L (enzyme)	0.249	0.249
Novo AMG 300 L (enzyme)	0.719	0.719
Econase CE 15 (enzyme)	0.183	0.183
Yeast	0.089	0.089
Total		4.158

Production factors	Price [SEK/…]
Phosphoric acid (75%) [kg]	4.75
Sulphuric acid (93%) [kg]	1.94
Sodium hydroxic (50%) [kg]	1.48
Calcium chloride (30%) [kg]	2.06
Other chemicals [kg]	2.56
Scum reduction agent [kg]	20.00
Enzymes [kg]	32.80
Yeast [kg]	0

A3.1.2 The emission and energy requirement per kg chemical

The figures for energy requirement and the emissions emitted during the research that the research are based upon is here presented.

Chemical	CO_2 [g/kg]	CO [g/kg]	HC [g/kg]	CH_4 [g/kg]	NO_x [g/kg]	SO_x [g/kg]	NH_3 [g/kg]	Particles [g/kg]	Input energy [MJ/kg]
Phosphoric acid[a]	1600	0.26			3.1	7.88		0.6	20
Sulphuric acid[a]	239	0.039			0.46	1.18		0.09	3
Sodium hydroxide[a]	364	0.111	0.0043	0.00065	1.51	1.29		0.00046	10.41
Calcium chloride[b]	141	0.045	0.0043		0.58	0.76			1.55
Other chemicals[c]	586	0.114	0.0043	0.00065	1.41	2.78		0.23	8.74
Scum reduction agent[c]	586	0.114	0.0043	0.00065	1.41	2.78		0.23	8.74
Novo BAN 240 L (enzyme)[d]	280	0.165	0.034	0.00024	1.66	1.17	0.014	0.077	6.32
Novo AMG 300 L (enzyme)[d]	280	0.165	0.034	0.00024	1.66	1.17	0.014	0.077	6.32
Econase CE 15 (enzyme)[d]	280	0.165	0.034	0.00024	1.66	1.17	0.014	0.077	6.32
Yeast[a]	280	0.165	0.034	0.00024	1.66	1.17	0.014	0.077	6.32

(Source: Bernesson, 2004)

A3.2 Swedish average electricity, the emissions emitted and the energy requirement

Here the energy requirement and the emissions emitted during the production of electricity that the research is based upon are presented. The different sources for electricity on the Swedish market and its share of the total electricity production are presented.

Type of electricity	Share [%]	Ref.[b]	Efficiency [%]	Ref.[b]	Energy use [MJ/MJ_{el}]	Ref.[b]	Total energy use [MJ_{pr}/MJ_{el}]
Hydro power	48.2		100		0.0037	1	0.484
Nuclear power	44.3	1	33	2	0.061	1	1.369
Wind power	0.2		100		0.029	1	0.0024
CHP[a], oil	1.3	1	85	2	0.078	1	0.017
CHP[a], coal	2.4	1	85	2	0.050	1	0.030
CHP[a], natural gas	0.5	1	85	2	0.067	1	0.0058
CHP[a], biofuels	2.8	1	85	2	0.046	1	0.034
Cold condensing, oil	0.2	1	40	2	0.13	1	0.0053
Grid loss, large-scale, machinery	5.0	2					0.097
Total:							2.045

CO_2 [g/MJ_{el}]	CO [mg/MJ_{el}]	HC [mg/MJ_{el}]	CH_4 [mg/MJ_{el}]	NO_x [mg/MJ_{el}]	SO_x [mg/MJ_{el}]	NH_3 [mg/MJ_{el}]	N_2O [mg/MJ_{el}]	HCl [mg/MJ_{el}]	Particles [mg/MJ_{el}]	Input energy [MJ/MJ_{el}]
8.234	18.9	3.05	51.5	15.8	13.7	0.23	0.75		2.63	2.045

(Source: Bernesson, 2004)

A3.3 The emission and energy requirement for diesel

The figures for energy requirement and the emissions emitted during the diesel consumptions and production that the research based upon is here presented.

Production factor	CO_2 [g/ha]	CO [g/ha]	HC [g/ha]	CH_4 [g/ha]	NO_x [g/ha]	SO_x [g/ha]	N_2O [g/ha]	Particles [g/ha]	Input energy [MJ/ha]
Diesel fuel consumption	169077	188.08	56.38		2011.26	1.07		25.48	2316.12
Production of diesel fuel	8106	4.63	76.43	4.63	71.80	44.01	0	2.32	138.97
Production of lubrication oil	57	0.03	0.54	0.03	0.50	0.31	0	0.02	0.98

A4 Energy input by activity

This table is summarising the total energy input, divided by different activities. These are based on the assumptions about taken in section 4.1.2.1 and 4.1.2.2 and are calculated based on the aggregated values shown in table 4.1

Total Input of energy in the production of bioethanol GJ		
	GJ TOTAL	**%**
Factory	**663,119**	**87%**
Electricity (fermentation & distillation of bioethanol)	251,416	33%
Electricity (animal feed only)	262,242	35%
Steam (fermentation & distillation of bioethanol)	42,308	6%
Steam (animal feed only)	42,210	2%
Machinery and building material	11,834	1.6%
Handling of waste water	40,539	5%
Production and transportation of chemicals *	12,570	1.7%
Transportation	**40,853**	**13%**
Transport of animal feed from factory	14,060	2%
Transport of produced bioethanol fuel	26,793	4%
TOTAL ENERGY INPUT (GJ)	**703,972**	**100%**

A5 CO_2 equiv. emissions emitted during different steps of the production of bioethanol,

Here the CO2 emissions are summarised from the assumptions taken in section 4.1.2.1 and 4.1.2.2 and are calculated based on the aggregated values shown in table 4.1.

CO_2 emissions during production	**of bioethanol**	
	Total (tonnes)	**%**
In the bioethanol factory	**13,867**	**67%**
Electricity (fermentation & distillation of bioethanol)	1,190	5.8%
Electricity (animal feed only)	1,241	6.0%
Steam (fermentation & distillation of bioethanol)	5,122	25%
Steam (animal feed only)	5,110	25%
Machinery and building material	56	0.3%
Handling of waste water	192	0.9%
Production and transportation of chemicals	957	4.6%
Transportation	**2,762**	**33%**
Transport of animal feed from factory	969	4.7%
Transport of produced bioethanol fuel	1,793	9%
TOTAL CO_2 equivalent.	**16,629**	**100%**

A6 The spreadsheet that calculates the NPV and IRR for SvL

In this spreadsheet the net cash flow per annum is used to get the financial IRR and the NPV. The sensitivity analysis for changes in the prices for energy, cereals and bioethanol is made in this spreadsheet.

Microsoft Excel - Social appraisal of bioethanol production

Table 2

Project net cash flows for the bioethanol factory

		0	1	2	3	
Investment cost						
Fixed investment		-1 420 000 000				
Working capital			0			
Total investment		-1 420 000 000				
Operating cost			-929 115 062	-929 115 062	-929 115 062	-929 115 0[illegible]
Revenuse			1 390 000 000	1 390 000 000	1 390 000 000	1 390 000 0[illegible]
Net cash flow		-1 420 000 000	460 884 938	460 884 938	460 884 938	460 884 9[illegible]
(Before financing and tax)						

NPV and IRR for SvL for prodcution of bioethanol

Interest rate	1,8%	5%	10%	15%
NPV	4 591 610 421	3 363 828 049	2 085 527 480	1 274 964 804
IRR	32%			

The NPV and IRR for SvL if the energy costs would rise with 20%

Interest rate	1,8%	5%	10%	15%
NPV	4 273 700 229	3 110 846 305	1 900 145 721	1 132 447 788
IRR	30%			

The NPV and IRR for SvL if the price for cereals would rise by 20%

Interest rate	1,8%	5%	10%	15%
NPV	3 052 462 639	2 139 028 401	1 188 010 098	584 975 133
IRR	23%			

Project CBA / Private CBA / Social CBA / Refent gr.CBA / calc

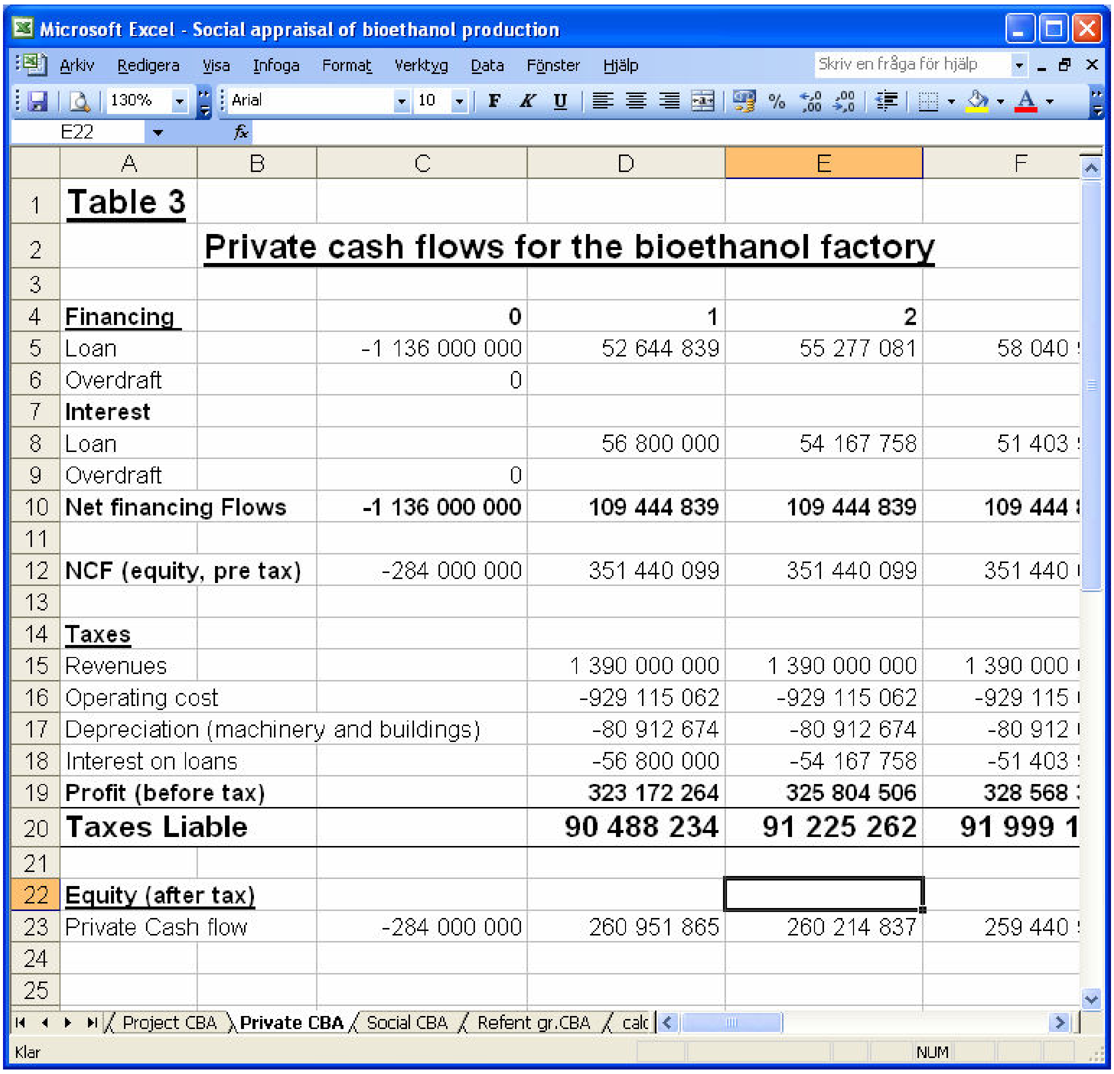
A7 Changes in the price of input and output and its influence of the NPV and IRR

The calculations in the table below test how sensitive SvL's investment in bioethanol production is to changes in the prices on the inputs used and the outputs under the taken assumptions. This is all assuming that all other variables are the same and compared with the figures presented in table 4.3. If the cost for energy (electricity and steam) would rise by 20% the IRR would fall by 2%. If the cost for cereals on the other hand would increase by 20% the effect would be -9% for the IRR. The sensitivity to changes in the price of bioethanol is however higher. If this price falls by 20% the IRR would according to the taken assumptions only be 15%.

The NPV and IRR for SvL with changes in input/output prices				
Rise in energy cost by 20%*				
Interest rate	1.8%	5%	10%	15%
NPV	4,273,700,229	3,110,846,305	1,900,145,721	1,132,447,788
IRR	30%			
Rise in the cost for cereals by 20%*				
Interest rate	1.8%	5%	10%	15%
NPV	3,052,462,639	2,139,028,401	1,188,010,098	584,975,133
IRR	23%			
Decrease of the price for bioethanol by *				
Interest rate	**1.8%**	**5%**	**10%**	**15%**
NPV	1,435,053,106	851,950,804	244,856,240	-140,098,760
IRR	13%			
* assuming everything else equal				

A8 The spreadsheet that calculates the company tax and the equity after tax

The financing of the fixed investment is calculated assuming that the loan taken by SvL is an annuity loan (further explained in appendix A9) with a period of repayment of 15 years. This signifies that the cost per annum is constant over time and it is only the ratio of interest and instalments that changes over time. The ratio of the interest rate is higher in the beginning of the period and it then decreases over time whereas it is the opposite for the instalments. The company tax, which is 28% in Sweden, is based on the value gotten when subtracting the revenues with the operation costs, cost for depreciation and interest of loans.



	A	B	C	D	E	F
1	**Table 3**					
2		**Private cash flows for the bioethanol factory**				
3						
4	**Financing**		**0**	**1**	**2**	
5	Loan		-1 136 000 000	52 644 839	55 277 081	58 040
6	Overdraft		0			
7	**Interest**					
8	Loan			56 800 000	54 167 758	51 403
9	Overdraft		0			
10	**Net financing Flows**		**-1 136 000 000**	**109 444 839**	**109 444 839**	**109 444**
11						
12	**NCF (equity, pre tax)**		-284 000 000	351 440 099	351 440 099	351 440
13						
14	**Taxes**					
15	Revenues			1 390 000 000	1 390 000 000	1 390 000
16	Operating cost			-929 115 062	-929 115 062	-929 115
17	Depreciation (machinery and buildings)			-80 912 674	-80 912 674	-80 912
18	Interest on loans			-56 800 000	-54 167 758	-51 403
19	**Profit (before tax)**			**323 172 264**	**325 804 506**	**328 568**
20	**Taxes Liable**			**90 488 234**	**91 225 262**	**91 999 1**
21						
22	**Equity (after tax)**					
23	Private Cash flow		-284 000 000	260 951 865	260 214 837	259 440
24						
25						

A9 The annuity method

$$Acc = (A - R * P) * An * \left(\frac{U}{D}\right)$$

where: A = Replacement value;
R = Residual value;
U = Use [h/ha] and
D = Annual use [h/year].

The present value factor:

$$P = \frac{1}{\left(1 + \frac{i}{100}\right)^{C}}$$

where: i = Calculation interest;
C = Length of life [years], calculated.

The fixed annual factor:

$$An = \frac{\frac{i}{100} * \left(1 + \frac{i}{100}\right)^{C}}{\left(1 + \frac{i}{100}\right)^{C} - 1}$$

The annual capital cost for depreciation is calculated with the annuity method. The replacement value used for the machinery and buildings are the initial investment cost. For buildings it is assumed that the residual value is 0 % of replacement value and for machinery it is assumed to be 25%. The interest rate is assumed to be 5% and the machinery are expected to have 15 years life time and the buildings are expected to last for 50 years. This adds up to an annual capital cost of 80,912,674 SEK/annum; 6,133,149 for buildings and 74,779,525 for the machinery.

(Source: Bernesson, 2004)

A10 The valuation of CO_2 emissions

A 10.1 Cost for CO2 emissions emitted during production of bioethanol

In this table the values presented in appendix A5 is used. These figures are multiplied with 14, 132 respective 238 SEK per tonne CO_2 emissions in order to get an aggregated value for the SCC occurring during the production process.

16,629*tonnes*	**Pearce**	**AIE, SEI**	**FUND**
SEK /tonne CO_2 emissions	**14**	**132**	**238**
In the bioethanol factory	**192,196**	**1,835,938**	**3,304,688**
Electricity (ferm.& distil)	16,498	157,591	283,664
Electricity (animal feed only)	17,199	164,291	295,723
Steam (ferm.& distil)	70,985	678,081	1,220,545
Steam (animal feed only)	70,820	676,505	1,217,710
Machinery and building material	776	7,414	13,346
Handling of waste water	2,658	25,394	45,708
Prod. & transportation of chemicals	13,260	126,662	227,992
Transportation	**38,283**	**365,692**	**658,245**
Transport of animal feed	13,429	128,279	230,902
Transport of bioethanol fuel	24,854	237,413	427,343
TOTAL COST	**230,479**	**2,201,630**	**3,962,934**

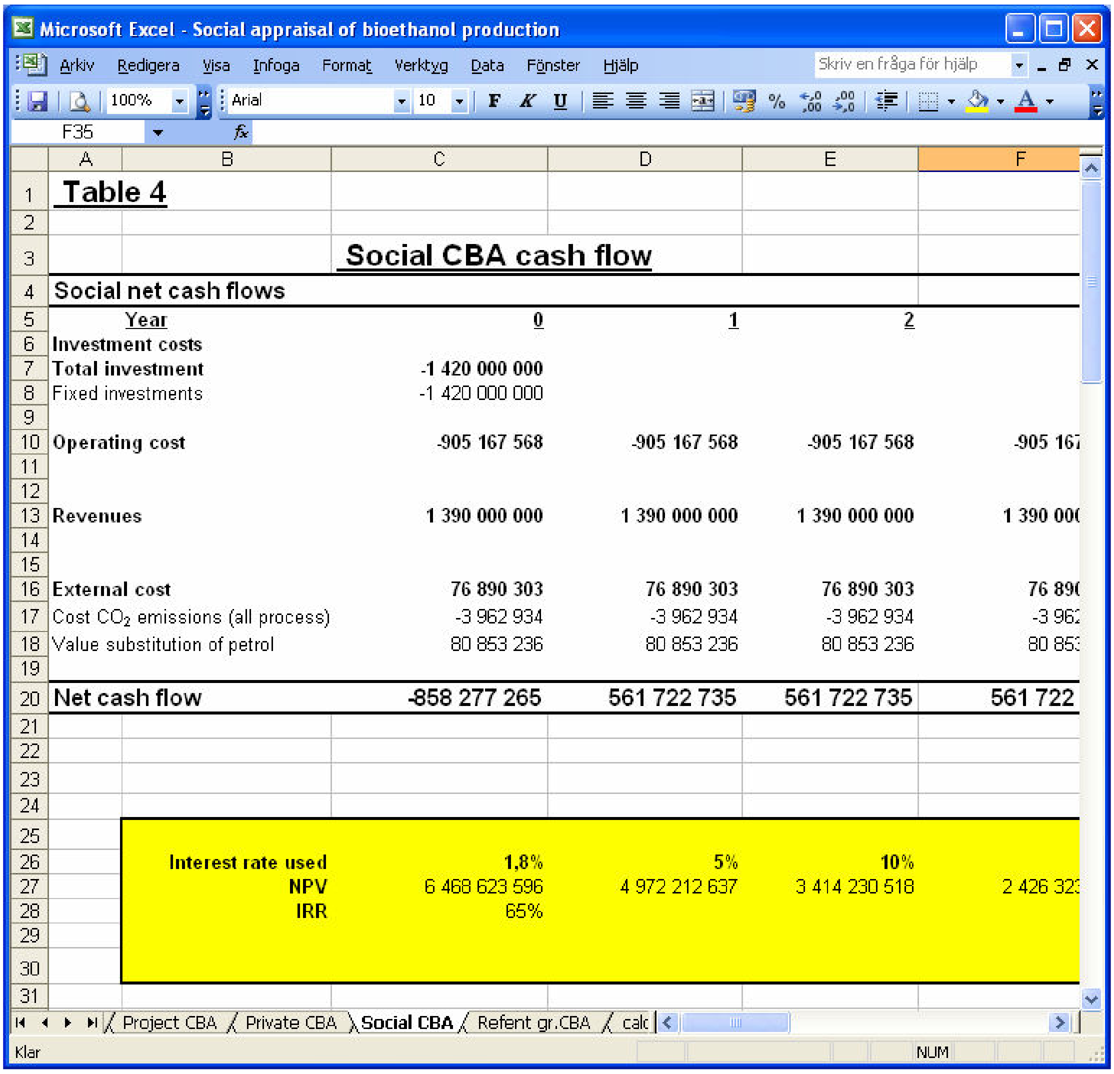
A10.2 Value of total CO_2 reduction from substitution of petrol with bioethanol

In this table the SCC for the CO_2 that is not emitted due to substitution of petrol with bioethanol is presented, valued after 14, 132 and 238 SEK per tonne.

340 000 tonnes	*SEK/ton*	*Total SEK*
Pearce	14	**4,749,820**
AIE, SEI	132	**44,918,465**
FUND	238	**80,853,236**

A11 Spreadsheet to calculate the social NPV

In this spreadsheet the adjusted net cash flow per annum is used to get the social IRR and the NPV. The sensitivity analysis for changes in the prices for energy, cereals and bioethanol is also by using this spreadsheet



Microsoft Excel - Social appraisal of bioethanol production

Table 4

Social CBA cash flow

	A/B	C	D	E	F
4	Social net cash flows				
5	Year	0	1	2	
6	Investment costs				
7	Total investment	-1 420 000 000			
8	Fixed investments	-1 420 000 000			
9					
10	Operating cost	-905 167 568	-905 167 568	-905 167 568	-905 167
11					
12					
13	Revenues	1 390 000 000	1 390 000 000	1 390 000 000	1 390 000
14					
15					
16	External cost	76 890 303	76 890 303	76 890 303	76 890
17	Cost CO_2 emissions (all process)	-3 962 934	-3 962 934	-3 962 934	-3 962
18	Value substitution of petrol	80 853 236	80 853 236	80 853 236	80 853
19					
20	Net cash flow	-858 277 265	561 722 735	561 722 735	561 722
26	Interest rate used	1,8%	5%	10%	
27	NPV	6 468 623 596	4 972 212 637	3 414 230 518	2 426 32
28	IRR	65%			

Project CBA / Private CBA / Social CBA / Refent gr.CBA / calc

A12 Changes in the price of input and output and its influence of the social NPV and IRR

*A12.1The social NPV with 20% increase in energy prices**

Fund				
Interest rate used	**1.8%**	**5%**	**10%**	**15%**
NPV	6,127,396,415	4,695,713,616	3,205,122,956	2,259,948,414
IRR	**61%**			
AIE, SEI				
Interest rate used	1.8%	5%	10%	15%
NPV	5,647,477,037	4,306,831,237	2,911,023,374	2,025,950,031
IRR	**55%**			
Pearce				
Interest rate used	1.8%	5%	10%	15%
NPV	5,107,141,930	3,868,993,526	2,579,900,405	1,762,494,237
IRR	**49%**			

*A12.2 The social NPV with 20% increase in the cost for cereals**

Fund				
Interest rate used	**1.8%**	**5%**	**10%**	**15%**
NPV	4,811,475,814	3,629,412,989	2,398,713,137	1,618,333,788
IRR	**45%**			
AIE, SEI				
Interest rate used	1.8%	5%	10%	15%
NPV	4,331,556,437	3,240,530,610	2,104,613,555	1,384,335,406
IRR	**40%**			
Pearce				
Interest rate used	1.8%	5%	10%	15%
NPV	3,791,221,330	2,802,692,899	1,773,490,586	1,120,879,611
IRR	**35%**			

*A12.3 The social NPV with an decrease in price for bioethanol 20%**

The calculations in this table test how sensitive the social NPV are to the changes in input and output prices introduced in A9. It is shown that if everything else is keep the same the drop in social NPV is considerable compared with the original data this calculation. It is found, as in A9that the social NPV is most sensitive to changes in the price for bioethanol followed by price increases of the cereals used.

Fund				
Interest rate used	**1,8%**	**5%**	**10%**	**15%**
NPV	3 070 066 281	2 218 335 392	1 331 559 278	769 259 896
IRR	**28%**			
AIE, SEI				
Interest rate used	1,8%	5%	10%	15%
NPV	2 590 146 903	1 829 453 013	1 037 459 696	535 261 513
IRR	**24%**			
Pearce				
Interest rate used	1,8%	5%	10%	15%
NPV	2 049 811 797	1 391 615 302	706 336 727	271 805 719
IRR	**20%**			
*assuming everything else equal				

A13 Distributional effects for groups within the Swedish society

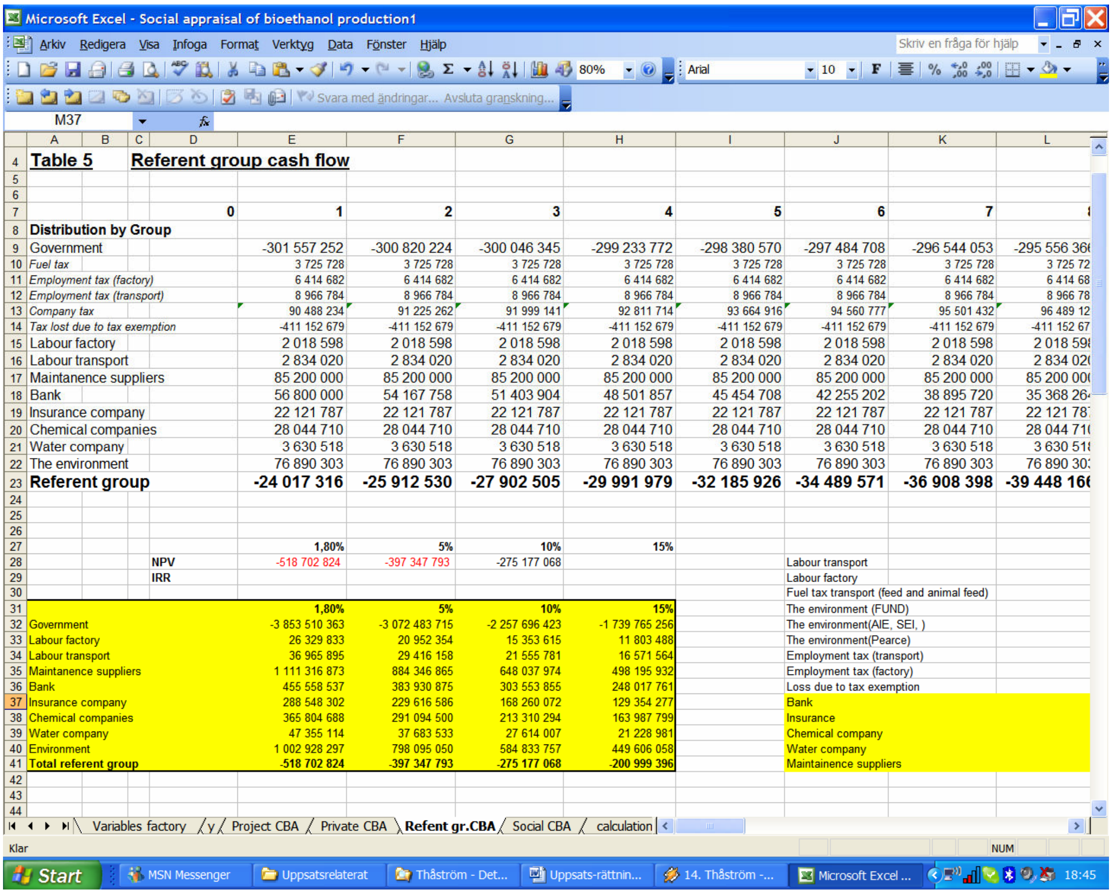


Table 5 Referent group cash flow

	0	1	2	3	4	5	6	7	8
Distribution by Group									
Government		-301 557 252	-300 820 224	-300 046 345	-299 233 772	-298 380 570	-297 484 708	-296 544 053	-295 556 36
Fuel tax		3 725 728	3 725 728	3 725 728	3 725 728	3 725 728	3 725 728	3 725 728	3 725 72
Employment tax (factory)		6 414 682	6 414 682	6 414 682	6 414 682	6 414 682	6 414 682	6 414 682	6 414 68
Employment tax (transport)		8 966 784	8 966 784	8 966 784	8 966 784	8 966 784	8 966 784	8 966 784	8 966 78
Company tax		90 488 234	91 225 262	91 999 141	92 811 714	93 664 916	94 560 777	95 501 432	96 489 12
Tax lost due to tax exemption		-411 152 679	-411 152 679	-411 152 679	-411 152 679	-411 152 679	-411 152 679	-411 152 679	-411 152 67
Labour factory		2 018 598	2 018 598	2 018 598	2 018 598	2 018 598	2 018 598	2 018 598	2 018 59
Labour transport		2 834 020	2 834 020	2 834 020	2 834 020	2 834 020	2 834 020	2 834 020	2 834 02
Maintanence suppliers		85 200 000	85 200 000	85 200 000	85 200 000	85 200 000	85 200 000	85 200 000	85 200 00
Bank		56 800 000	54 167 758	51 403 904	48 501 857	45 454 708	42 255 202	38 895 720	35 368 26
Insurance company		22 121 787	22 121 787	22 121 787	22 121 787	22 121 787	22 121 787	22 121 787	22 121 78
Chemical companies		28 044 710	28 044 710	28 044 710	28 044 710	28 044 710	28 044 710	28 044 710	28 044 71
Water company		3 630 518	3 630 518	3 630 518	3 630 518	3 630 518	3 630 518	3 630 518	3 630 51
The environment		76 890 303	76 890 303	76 890 303	76 890 303	76 890 303	76 890 303	76 890 303	76 890 30
Referent group		**-24 017 316**	**-25 912 530**	**-27 902 505**	**-29 991 979**	**-32 185 926**	**-34 489 571**	**-36 908 398**	**-39 448 16**

	1,80%	5%	10%	15%
NPV	-518 702 824	-397 347 793	-275 177 068	
IRR				

	1,80%	5%	10%	15%
Government	-3 853 510 363	-3 072 483 715	-2 257 696 423	-1 739 765 256
Labour factory	26 329 833	20 952 354	15 353 615	11 803 488
Labour transport	36 965 895	29 416 158	21 555 781	16 571 564
Maintanence suppliers	1 111 316 873	884 346 865	648 037 974	498 195 932
Bank	455 558 537	383 930 875	303 553 855	248 017 761
Insurance company	288 548 302	229 616 586	168 260 072	129 354 277
Chemical companies	365 804 688	291 094 500	213 310 294	163 987 799
Water company	47 355 114	37 683 533	27 614 007	21 228 981
Environment	1 002 928 297	798 095 050	584 833 757	449 606 058
Total referent group	**-518 702 824**	**-397 347 793**	**-275 177 068**	**-200 999 396**

Labour transport
Labour factory
Fuel tax transport (feed and animal feed)
The environment (FUND)
The environment(AIE, SEI,)
The environment(Pearce)
Employment tax (transport)
Employment tax (factory)
Loss due to tax exemption
Bank
Insurance
Chemical company
Water company
Maintainence suppliers

In this spreadsheet it is calculated how much each group within the Swedish society benefit form SvL's investment in bioethanol production. The distribution to the government consists of several aggregated values; The fuel tax received by the government is here the tax paid on electricity in the factory and the tax paid for diesel used during the transportation, the figures presented in 4.2 subtracted with the values in table 4,4. The employment tax is the 32.28% of the gross income that is paid for the labour used in the project, calculated upon the figures in table 4.2 and the level of company tax are taken from appendix A8. For the government the cost for tax exemption on biofuels should also be included here even thought it is not included in the CBA since it is a transfer tax. The cost of the tax exemption is calculated from the amount of petrol that the produced bioethanol substitutes (about 144 000m3) times the energy tax (2,86SEK/litre petrol, Swedish tax agency, 2006) that the government never receives. The government's loss of carbon tax revenue will however not be considered in the distributional effects because it is a loss due improved environmental performance of bioethanol compared to fossil fuels. It would be unfair to account bioethanol for the revenue loss since it is one of the government's major policy goals.

The benefit used for the labour is the 15% of the employees that are assumed to otherwise be unemployed, gross income salary times 0.15. This is 18.28 SEK/h with a salary of 180SEK respective 30.47SEK/h if the salary is 300SEK. The figures regarding chemical-, water- , insurance and maintenance companies are all adapted directly from table 4.2. The price paid for the insurance is assumed to be 50% of the various costs. The benefit for the bank is the interest rate paid for the loan, adapted from A8. For the environment the aggregated net savings for the three different values for SCC is used.

A14 Assumptions for a different without the project scenario

In this section the assumptions taken to get the information presented in section 4.4 is discussed. It is assumed that the wheat is produced conventionally with fertilizers and chemicals. First there are summaries of the total CO_2 emitted and energy requirement during the whole production process of bioethanol, including the cultivation of the wheat. The assumptions taken to get this are then presented and explained. The information for this is largely adapted from Bernesson (2004) and should be seen as indicative results.

CO_2 emissions emitted during the production process, all cultivation included

	Total	%
Cultivation of wheat	**221 044**	**91%**
Production of fertilizer	105 668	44%
Soil emissions	69 584	29%
Tractor activities	17 773	7%
Heat for seed drying	18 084	7%
Electricity for drying the cereals	244	0,1%
In the bioethanol factory	**13 867**	**6%**
Electricity (fermentation & distillation)	1 190	0,5%
Electricity (animal feed only)	1 241	0,5%
Steam (fermentation & distillation)	5 122	2%
Steam (animal feed only)	5 110	2%
Machinery and building material	56	0,0%
Handling of waste water	192	0,1%
Production and transportation of chemicals	957	0,4%
Transportation	**6 819**	**3%**
Transport of wheat to factory	4 057	2%
Transport of waste from factory	969	0,4%
Transport of produced bioethanol fuel	1 793	1%
TOTAL CO_2 equiv.	**241 731**	**100%**

Energy requirement during the whole production process, all cultivation included

	GJ TOTAL	%
Cultivation of wheat	**1 313 909**	**63%**
Tractor activities (diesel incl. production of diesel and oil)	244 088	12%
Heat for drying (incl. production of the fuel)	248 733	12%
Fertiliser (manufacturing and spreading)	576 026	28%
Electricity for drying the seed	51 632	2%
Pesticides	29 250	1%
Factory	**663 119**	**32%**
Electricity (fermentation & distillation)	251 416	12%
Electricity (animal feed only)	262 242	13%
Steam (fermentation & distillation)	42 308	2%
Steam (animal feed only)	42 210	2%
Machinery and building material	11 834	0,6%
Handling of waste water	40 539	2%
Production and transportation of chemicals	12 570	0,6%
Transportation	**96 686**	**5%**
Transport of wheat to factory	55 833	3%
Transport of waste from factory	14 060	1%
Transport of produced bioethanol fuel	26793	1%
TOTAL ENERGY (GJ)	**2 073 714**	**100%**

The tractors used for cultivation are assumed to be driven on diesel and used for about 6 hours per ha which give a fuel consumption of about 66 l/ha. Lubrication oil is also used here. In the table below it is shown how this is assumed to be divided between different field activities per ha and the assumed diesel consumption for these activities. (Bernesson, 2004)

Field operation	Use	MK1	
	[h/ha]	[l/h]	[l/ha]
Tractor, 52 kW[a]	1.02		
Tractor, 66 kW[a]	3.65		
Plough	2.06	11.3	23.4
Harrow, 2 times[a]	0.52	13.4	6.9
Seed drill[a]	0.43	8.2	3.6
Cambridge roller	0.12	12.4	1.4
Fertiliser spreader, 2 times	0.26	7.2	1.9
Sprayer, 2.8 times	0.21	6.2	1.30
Threshing machine	1.36	11.3	15.5
Disc harrow, 1 time[a]	0.74	13.4	9.8
Tipping trailer (field – farm)	0.28	6.2	1.74
Front-loader	0.05	5.2	0.26
Sum	6.03		65.8

(Source, Bernesson, 2004)

The energy input and the emissions that is assumed to be emitted from the field operation per ha is presented in the table below. This signifies that about 2.7kg CO_2 emission equivalent is emitted per litre diesel This includes production of diesel and lubrication oil which is assumed to constitute about 4.5 % of the total CO_2 emissions and 8% of the energy input (this is the same also for the diesel used for transportation). (Bernesson, 2004)

Production factor	CO_2	CO	HC	CH_4	NO_x	SO_x	N_2O	Particles	Input energy
	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[MJ/ha]
Tractive power:									
Diesel fuel consumption	169077	188.08	56.38		2011.26	1.07		25.48	2316.12
Production of diesel fuel	8106	4.63	76.43	4.63	71.80	44.01	0	2.32	138.97
Production of lubrication oil	57	0.03	0.54	0.03	0.50	0.31	0	0.02	0.98
Total emissions tractive power	177240	192.74	133.35	4.66	2083.56	45.38	0	27.81	2456.07

(Source, Bernesson, 2004)

The fertilizer used is assumed to be 120 N/ha, 17kg P/ha and 30 kg K/ha and requires in total 535kg fertilizer per ha to cover this requirement. Including transportation this gives about 2 tonnes CO_2 per ton fertilizer and an energy input of average 10.7 GJ/tonne fertilizer. It is assumed that there are emissions to the soil that are dependent on the supply of nitrogen and the data used for these calculations, adapted from Bernesson (2004) is 40g NH_3 /kg nitrogen and 19.6g N_2O/ kg nitrogen For the chemicals used for cultivation of wheat the total active substance used per ha/year is calculated to be 1.48kg/ha and the energy requirement per kg is assumed to be 198MJ/kg active substance. (Bernesson, 2004) The emissions and the energy input per kg chemicals and fertilizer that the calculations are based upon are presented below.

Factor of production	CO_2	CO	HC	CH_4	NO_x	SO_x	NH_3	N_2O	HCl	PAH	Particles	Energy requirement
	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[g/kg]	[MJ/kg]
Manufacturing of fertiliser NPK 20-3-5 S B[a]	749	0.18	0.44	0.75	1.5	2.3	0.15	3.8	0.049	0.000080	0.228	10.3
Manufacturing of fertiliser NPK 21-4-7 S[a]	746	0.21	0.50	0.76	1.6	2.8	0.16	3.5	0.047	0.000076	0.250	10.2
Manufacturing of fertiliser N 28[a]	931	0.11	0.34	0.87	1.5	1.3	0.21	5.6	0.065	0.000107	0.228	12.7
Manufacturing of pesticide active substances[b]	4921	2.66	0.29	0.18	6.9	17.4	0.16	1.5	0.21		0.043	198

(Source, Bernesson, 2004)

The wheat is assumed to be dried before the sale to the bioethanol factory and it is assumed that this is done at the farms using hot-air dryers that use oil as energy. The electricity used for drying the cereals is assumed to be 0.038MJ electricity to get the water content of 1kg wheat from 20% to 14%./kg. The amount of oil needed for the drying of the wheat comes from the assumption that 0.15 litres oil is required per kg water. This means that it is assumed that 442.5 kg water is removed/ ha and that 66 l heating oil is used/ha. (Bernesson, 2004) Below the emissions and energy requirement that this is calculated on for production and consumption of this energy is presented.

Production factor	CO_2	CO	HC	CH_4	NO_x	SO_x	NH_3	N_2O	Particles	Input energy
	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[g/ha]	[MJ/ha]
Heat for drying:										
Production of drying fuel	8213	4.69	77.44	4.69	72.74	44.58		0.00	2.35	140.79
Combustion of drying fuel	171298	70.40	11.73	16.43	70.40	1.08		2.35	2.35	2346.54
Total emissions heat for drying	179510	75.09	89.17	21.12	143.14	45.67		2.35	4.69	2487.33
Electricity for drying and cleaning of the seed:										
Electricity consumed in rural area	2079	4.77	0.77	12.99	3.98	3.45	0.058	0.19	0.66	516.32

The input of labour is assumed to be 6.03 working hours /ha. This adds up to 600 000 working hours for the cultivation which equals 326 yearly employment positions (assuming normal working circumstances, 40h/week* 46weeks/year). (Bernesson, 2004)

The wheat is assumed to be transported 110km to the bioethanol factory in tractors by the farmers. The total labour required is 230 000h (2.3h/ha for loading, unloading and transport) which equals 125 yearly employment positions with same assumptions as above. For this 142 000m^3 diesel is used. (Bernesson, 2004) During this transportation 2% or 4000 tonnes CO_2 equiv. is released.

The table below illustrates the total the assumption the total inputs that the calculations for this is based upon. The total CO_2 emissions presented here is 225 000 tonnes more than in the basic scenario in this research. The energy input is about 1370 GJ more.

Outputs

Inputs

Production of wheat

Outputs from cultivation of wheat

Outputs
Open landscape*
Employment for farmers

CO_2 equiv: 221 000 tonnes *(91% of total emissions in the process)*

Inputs for cultivation of wheat

Seed	23 100 t.
Fuel for tractor	6 620 m^3
Fertiliser	53 500 t.
Pesticide**	
Electricity for drying	6.7 GWh
Fuel for drying	6 670 m^3
Machinery	
Labour	432 000 h
Land	100 000ha

Energy input: 1 314 000GJ
(63% of total energy input in the process)

Transport of wheat from farm

Outputs from transport

Outputs
Employment

CO_2 equiv.:4000 tonnes *(2% of total emissions in the process)*

Inputs for transport done by farmers

Diesel for tractors	142 m^3
Labour	230 000h

Energy Input: 56 000GJ *(3% of total energy input in the process)*

The bioethanol plant

Outputs from bioethanol factory

Outputs

Bioethanol	220 000 m3
Feed	180 000 tonnes
Waste water	106 000 m3

CO_2 equiv: 14 000 tonnes *(6% of total emissions in the process)*

Inputs in the bioethanol factory

Grain	590 000 tonnes
Steam	590 GWh
Electricity	77 GWh
Water	530 000 m^3
Labour	66 240 h
Chemicals**	

Energy Input: 663 000 GJ *(32% of total energy input in the process)*

Transport of bioethanol and feed

Outputs from transport
Outputs
Employment

CO_2 equiv: 2700 tonnes *(6% of total emissions in the process)*

Inputs for transport

Diesel for the lorry	914m^3
Labour	150 000 h

Energy Input: 41 000 GJ *(2% of total energy input in the process)*

Usage of bioethanol and feed

Bioethanol: substitutes 144 000 m^3 petrol *(only "green" CO_2 during combustion)*

Animal feed: Substitutes 180 000 tonnes Soya

Reduced oil dependency*

Total
Total Energy input: 2 074 000 GJ
Total CO_2 equiv. 240 000 tonnes

* Has not been quantified in monetary terms in this study
** CO_2 emissions only have been accounted for.

The Swedish University of Agricultural Sciences, Johanna Larsson, 2007

Pris: 100:- (exkl moms)

Tryck: SLU, Institutionen för ekonomi, Uppsala 2007

Distribution:

Sveriges lantbruksuniversitet
Institutionen för ekonomi
Box 7013
750 07 Uppsala

Swedish University of Agricultural Sciences
Department of Economics
P.O. Box 7013
SE-750 07 Uppsala, Sweden

Tel 018-67 2165
Fax + 46 18 673502